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# Desertification in the United States

## Status and Issues

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# Desertification in the United States

## Status and Issues

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# TABLE OF CONTENTS

Section I: Executive Summary....4

Section II: Desertification in the United States

A. Introduction....7
  1. Definition of Desertification....7
  2. History of the Project....8
  3. Background....9
  4. Purpose of Assessment....13

B. Natural Background....13
  1. Climate....15
  2. Geology and Soils....17
  3. Vegetation....19
  4. Biological Change and Climate....20
  5. Biological Diversity and Evolutionary Change....20
  6. Ecological Function....21

C. Historical Perspective....22

D. Desertification Processes and Manifestations....25
  1. Biological Resources....26
    a. Vegetation Changes: Quantity and Diversity....26
    b. Brush Infestation....27
    c. Changes in Animal Population....28
  2. Soils....36
    a. Erosion....36
    b. Nutrient Loss....45
    c. Compaction and Crusting....47
    d. Salinization of Soils....50
  3. Water....51
    a. Waterlogging....51
    b. Water Salinity Buildup....55
    c. Sedimentation....60

E. Dynamics of Desertification....63
  1. Feedback Mechanisms....63
  2. Competition for Resource Base....67
  3. Social and Economic Factors....69

F. Inventorying, Monitoring, and Trend Determination....73
  Introduction....73
  1. Data Base and Inventory....76
  2. Monitoring Principles....77
  3. Coordinating Environmental Data....77
  4. Limitations of Existing Monitoring Procedures....78
  5. Indicators of Desertification....78
  6. Monitoring and Assessment Systems of the United States....86
  7. The Potential of Remote Sensing Systems....86

G. Conservation: Programs and Practices....86

1. Institutional Responsibilities........................................87
2. Existing Legislation................................................88
3. Federal Conservation Programs......................................89
4. Conservation Practices..............................................92

H. Research Needs and Available Capabilities..........................103
1. The Importance of Interdisciplinary Research......................103
2. Sharing of Research Results........................................104
3. Forecasting........................................................105
4. Agriculture and Other Land Use Interactions........................105
5. American Indian Concerns...........................................107
6. Multi-Objective and Multi-Attribute Analysis.......................108
7. Risk and Impacts Analysis..........................................109
8. General Observations...............................................110
9. Available Capabilities.............................................110
10. Some Examples of Ongoing Relevant Projects........................116

Section III: Desertification Status and Issues: The Local Assessment

Introduction...........................................................118
A Survey of States' Views..............................................119
1. Background.........................................................119
2. Summary of Survey Findings.........................................120
3. Conclusions........................................................121

Appendices:

A. References and Selected Literature.................................125

B. Glossary...........................................................152

C. Abbreviations, Acronyms, and Conversions...........................164

D. Geographical Regions...............................................167

E. Ecological Regions.................................................173

F. Climatological Conditions of Arid and Semiarid Lands...............179

G. Soil...............................................................185

H. Water..............................................................187

I. Effect of Social Structure.........................................201

J. Economic Concerns..................................................208

K. Federal Institutional Responsibility................................216

L. Federal Legislation on Land and Natural Resources..................230

M. Monitoring Programs................................................241

N. Research Needs....................................................253

O. Working Groups and Staff........................................272

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Desertification Assessment in
the U. S. Project Staff

## Section I: Executive Summary

Patterns of land occupancy and consequent impacts and transformations in dry areas may result in the negative phenomenon, "desertification," defined as:

> the sustained decline and/or destruction of the biological productivity of arid and semiarid lands caused by man-made stresses, sometimes in conjunction with extreme natural events. Such stresses, if continued or unchecked, may lead to ecological degradation and ultimately to desert-like conditions.

Widespread drought, increasing degradation of land, and human suffering in parts of North Africa and the Middle East during the last decade led to a special United Nations Conference in Nairobi, Kenya in 1977 on desertification. The United States took a prominent role in the meeting and in the resulting actions which included contributing to a number of coordinated relief projects and providing expertise to surveys and special studies on the prevention of desertification.

Conferees at that meeting also agreed to the need for "plans of action" to be prepared by participating nations. The United States, for its part, determined that several constructive purposes could be served by the preparation of the present overview document "Desertification in the U. S.: Status and Issues." This is a one-time survey and assessment of important ongoing physical and social events which are affecting the quality of land resources in the extensive water-deficient areas of the Western States. Emphasis is placed on identification and description of dynamic processes set in motion or accelerated by man's actions which change the character of the land positively or negatively; of the technologies and institutional arrangements which have arisen to better monitor the effects of man's actions in the more fragile parts of the country; of the mitigating and preventive actions available to land managers and the progress made in combating desertification.

The report provides a holistic view of the actions and interactions which can lead to desertification. Thus, it includes summary information on component elements of the resource base drawn from more detailed and authoritative sources such as the Department of Agriculture's appraisals of soil conditions. It has not been possible to precisely measure, map, or categorize relative degrees of desertification in the regions of the United States; a principal finding is that the resource data base for the United States on which such determinations can be done has not been assembled, although the tools for accomplishing an overall inventory and subsequent periodic monitoring do exist and are identified.

The natural background or setting for the desertification assessment is the "dry domain," or region of net deficiency extending over the greater part of the United States west of the 100th meridian. The characteristics of the ecoregions are determined by unique combinations of climate, geology, topography, soils, vegetation, and animal life.

The present land uses in the West reflect the historical background, the phenomenal westward movement of the American nation, the development of modern means of production, and the accelerated growth of urban centers. Beneficial production and land management practices that developed based on experiences are described. Degradation of natural resources, where it occurred, generally reflects insufficient knowledge or failure to adopt suitable practices and safeguards which fully recognize the soil, site, and climate limitations.

Processes that contribute to desertification and its effects can be considered in three general groups: (1) biological resources; (2) soils; and (3) water. The changes in the amount and quality of vegetation, erosion, salinization, nutrient loss, crusting, and soil compaction are principal examples of manifestations. These in turn can be characterized in ways which provide indicators useful in detecting evidence of desertification and in calculating trends in the general condition of the resource base.

Desertification can only be understood and approached as a dynamic process. Many factors are operating simultaneously, depending on each other, and feeding back into the system. The subtle changes in an arid land ecosystem are difficult to use for trend identification and can have several consequences and ramifications, good and bad. A good understanding of the natural ecosystem characteristics and of the development potential requires a better knowledge of feedback mechanisms, the identification of competitors for available resources, and the consideration of social and economic opportunities, demands, and constraints.

Data gathering, analysis, and reporting are essential steps in determining the location and extent of desertification, where it exists. Identifying and measuring the recuperation or deterioration trends and potential is important as well, so as to predict and determine the success or failure of management plans and conservation programs. Available inventorying and monitoring systems, their capabilities and limits; the kind of desertification indicators that are or could be measured; the need for the integration of existing data, methods, and programs; and the potential use of remote sensing in determining long-term upward or downward trends are discussed.

Available procedures for the conservation of natural resources and control of desertification, existing programs, and institutions capable of and responsible for implementing these programs are briefly presented.

A considerable body of research results on the conservation of the dry domain renewable resources has been obtained, especially in the last fifty years. Application of some of these results have helped in the recuperation of some affected areas and provides the means for better management where used. Many unknowns still exist which, once uncovered, can influence and enhance the quality of life in arid regions. Future research must be aimed at cost-effective practices and at providing sufficient knowledge to make possible improved or alternative approaches to wise land-use decisions. In particular, arid zone interdisciplinary research is called for, as well as the integration of programs and capabilities.

A summary of views expressed by local and state institutions and individuals describes the perceived environmental transformations, the causes and effects of these changes, the effectiveness of programs and practices to cope with these transformations, and the pressures exercised by external and local demands on Western resources. The overriding concern was with the magnitude and pace of the environmental, economic, and social changes.

Three compelling reasons for carrying out national assessments of the status of desertification are: (1) greater scientific understanding; (2) increased public awareness; and (3) the ability and will to take responsible action. The desertification problem is multidisciplinary in scope and generally multijurisdictional in extent. Better understanding of the total impact of human and resource interaction in the dry areas of the country will lead to improved methods for combating desertification and strengthening the resource base of the Nation.

# Section II: Desertification in the United States

## A. Introduction

### 1. Definition of Desertification

Desertification has been defined for this assessment as

> the sustained decline and/or destruction of the biological productivity of arid and semiarid lands caused by manmade stresses, sometimes in conjunction with natural extreme events. Such stresses, if continued or unchecked, over the long term may lead to ecological degradation and ultimately to desert-like conditions.

Biological productivity refers to the naturally-occurring plant and animal life, as well as to the agricultural productivity of a given area.

The concept of "desertification" was first discussed in 1949 by Aubreville. In the 1960's it was used to describe the northward advance of the Sahara Desert in Algeria and Tunisia and the apparent southward extension of the Sahara in the West African Sahel region observed during that decade. Although the term describing human-induced barrenness of the land is relatively new to our vocabulary, the effects of desertification are not. As early as approximately 500-300 B.C., a Greek writer referred to the erosion and ruin of once-fertile lands along the coast of Turkey. The Seistan Desert (Iran and Afghanistan) was, until the 15th century, called the "granary of the East," and accounts of Alexander's advances into India describe virgin forests where now only deserts can be found. Some two thousand years before the present, the center of the Thar Desert in India was a jungle (Cloudsley - Thompson, 1977).

There are numerous accounts written since of famines and widespread migrations of peoples when lands forced to produce beyond their natural potential deteriorated into a condition in which they could produce no longer. More recently, near the end of World War II, the hills near Athens, Greece were stripped of the existing trees for firewood during an unusually cold winter. The high erosion of the denuded soil can be observed today.

The age of the problem, unfortunately, has not brought the wisdom to understand all the causes and prevention of desertification. As recently as the period 1968 to 1973, thousands of people and animals starved as the effects of the Sahel drought in West Africa were accented by past unwise management of the land.

### 2. History of the Project

The magnitude of the Sahel tragedy brought worldwide recognition of the increasing risk of desertification, and the United Nations called for a Conference on Desertification to be held in Nairobi in 1977. In hopes of filling some of the known research gaps in the knowledge about desertification, a number of special studies and workshops preceded and followed the international conference in Nairobi. The United States made major contributions to the study through provision of technical advice and active participation.

A greater appreciation of the complexity of the process, and an awareness of how much further research is needed about the subject of desertification also resulted. The 96 countries represented at the Nairobi conference jointly agreed to prepare national plans of action to combat desertification, and to share results of their individual research. It was recognized then as now that social, economic, and political factors vary greatly between countries and that human response will vary greatly according to local conditions.

The United States, as with other more developed countries such as Israel, has an excellent governmentally subsidized research system with which to study problems as they become obvious. The "third-world" or developing countries face a lack of established on-site research and monitoring capability as well as an accumulated data base for comparison use to establish trends. In addition, the U.S. arid and semi-arid lands, while increasing dramatically in population, have not faced the history of overpopulation as have countries in which overpopulation has led to tremendous pressures on the natural resources. Land denudation of firewood for fuel and cooking is a major cause of desertification in some countries, but it has not historically been significant in the western United States.

Cultural differences are also important. Overgrazing in the United States occurred previous to the 1930's, but it has since been largely controlled due to regulatory control and better grazing management systems by livestock producers. However, in countries where the killing of virtually any livestock is precluded because of cultural status attachment or religious beliefs, overgrazing continues to be a problem for which lack of technology, knowledge, or equipment is not the solution.

Nevertheless, U. S. policy supports international efforts to deal with some of the effects of desertification through several agencies' programs. The stability of governments is increasingly seen to depend not only on providing relief when need arises, but also in promoting sound land management to achieve better and sustained productivity. These cooperative activities are of great importance to our nation since the global supply and demand for food, forage, and fiber may determine the changes in the acreage of U. S. lands put under agriculture.

Following the 1977 United Nations Desertification Conference, the Department of State established an Interagency Task Force on Desertification in which the Departments of Agriculture and Interior, among others, participated actively. In late 1978, it was agreed that a report-survey on desertification in the United States should be prepared.

It was also agreed that the role of the Department of the Interior would be to lead the interagency study and overview of arid land problems and solutions, and relate it to the subject defined at the Nairobi Conference as "desertification." The Office of the Secretary determined that the Bureau of Land Management should provide principal support in view of its responsibility for managing large areas of public land under the multiple-use concept. The actual starting point in preparing the required report on desertification in the United States was in April 1979. A network of contacts was created to gather information and perform review. Represented were the public and private sectors, various levels of government, scientific and technical communities, and many interest groups. Each of the seventeen Great Plains and Western States were advised of the scope of this effort, and a request was made to the governors of these States to designate liaison persons to this project. In addition, Regional Commissions, Federal and State agency personnel, professional and producer societies, and interested parties were brought together to form a Task Force and a Steering Group to provide guidance to this endeavor.

The project has worked closely with its Mexican counterpart. Beginning as early as 1972, there has been United States--Mexico cooperation in the study of new crops, arid lands, agricultural productivity, and with most direct concern, desertification and the management of arid and semi-arid lands. There have been four annual bilateral meetings beginning in 1978, in which both countries have made recommendations, agreed to support corresponding research and monitoring projects, and have been kept appraised of relevant meetings and topics.

It should be noted that all the material used in this assessment was in prior existence, but unaggregated; it was provided to the Desertification in the U. S. project by people, institutions, and agencies with direct responsibilities for, and/or knowledge of, the management of renewable natural resources in the dry domain.

### 3. Background

The word desertification has been--and still is--used by many authors to describe degradation of various types and forms of vegetation, including the subhumid and humid forest areas, which has nothing to do with deserts either physically or biologically (Le Houerou, 1975).

But during the 1977 Nairobi Conference the definition adopted limited the discussions to the spread of desert-like conditions in arid and semiarid areas, with rainfall up to 600 mm only. It was considered that these are the areas at higher risk of becoming desertified. It is important to note that one-third of the total land area of the world is dry, and that many activities--of all kinds--occur there.

The climate of the world's dry biomes can be harsh, and the difficulties of wresting a livelihood from their resources may be harsher still. And yet, although these regions are still relatively sparsely populated, they are the homelands of 14 percent of the world's population, or 628 million people, and the number is increasing. Fifteen percent of these, or about 95 million people, are settled in the extremely arid regions.

Inhabitants of this dry domain have constantly sought ways to control and modify the environmemt to procure food, fiber, shelter, and amenities necessary for their existence. In so doing, the resource base has been manipulated, sometimes for the better, but sometimes also for the worse, as the stresses imposed have been too much for the land to withstand.

Aridity is the permanent climatic feature of regions with low average rainfall, low humidity, high climatic variations, high winds, high solar radiation incomes, extreme temperature variations, and unpredictable precipitation patterns (in time and space). In arid and semiarid lands the existing systems have evolved mechanisms at various levels of production that allow them to survive the very harsh conditions, extreme events such as droughts, the possible dessication due to secular climatic changes, and the natural, gradual weathering of soils. The changes brought about by shifts in climate occur at such a slow rate that, even acknowledging their probability, they are of marginal concern to the present assessment.

A clear distinction must be made between natural and manmade events that may affect an arid or semiarid region (Figure 1). One natural extreme event that may trigger or intensify desertification is drought. Drought is a random phenomenon and a temporary feature of the climate during which rainfall deviates appreciably below normal. Characteristically, it temporarily affects the hydrological system and the renewable resource base; it is generally coped with by short-term, crisis-responsive remedial measures; and the biota, if not under other extraneous stresses, possess appropriate recovery mechanisms. Characteristics of desertification, on the other hand are that: it is not a climatic feature; once established it may be a permanent condition; it occurs even when rainfall is above normal or when water has been made artificially available in a water-short area; it follows definite patterns; it may irreversibly affect the hydrologic system and the renewable resource base; the effects are long-lasting, and

## Figure 1: WATER SCARCITY IN ARID AND SEMI-ARID REGIONS

### A. DROUGHT - A NATURAL EVENT

TEMPORARY CHARACTERISTICS:

- Persistent lower-than-average precipitation
- Uncertain frequency, duration, severity
- Unpredictable occurrence
- Overall diminished water resources
- Diminished average carrying capacity of ecosystem

TRANSIENT EFFECTS:

- Deterioration of farm and rangelands; wind erosion
- Reduction of natural flora and fauna.
- Deterioration of air quality: dust
- Strained water supply systems

RESPONSES:

- Regulation, rationing and/or recycling of water
- Institutional "crisis-oriented" measures

### B. HUMAN-INDUCED SHORTAGES

TEMPORARY CHARACTERISTICS:

- Groundwater overdraft
- Reduced reservoir capacities
- Disturbed soil surface and subsurface: moderate land uses
- Increased runoff
- Decreased recharge
- Altered carrying capacity

TRANSIENT EFFECTS:

- Local hydrological systems affected
- Deterioration of water quality; saline intrusion/seep
- Competition among water users

RESPONSES:

- Regulation, rationing and/or recycling of water
- Increased value of water rights
- Institutional mitigating measures: conservation
- Technological innovations
- Changes in land uses, e.g., farmland conversions

### C. ARIDITY - A NATURAL CONDITION

PERMANENT CHARACTERISTICS:

- Overall low moisture
- High solar energy income
- Extreme temperature variations
- Highly variable precipitation in time and space
- Low annual average rainfall
- Low carrying capacity

PROTRACTED EFFECTS:

- Limited Agricultural productivity
- Industrial and extractive activities limited to water access
- Sparse human settlements
- Subsistence agriculture economy

RESPONSES:

- Land reclamation: irrigation
- Sequence of land conversions
- Water diversions, impoundments, conveyances

### D. HUMAN-INDUCED DEFICIENCIES

PERMANENT CHARACTERISTICS:

- Groundwater reduced or lost
- Loss of riparian systems
- Loss of soil nutrients and vegetation
- Damaged soil surface and subsurface: maximized land uses
- Increased flash flooding and runoff
- Deterioration and/or loss of carrying capacity

PROTRACTED EFFECTS:

- Water and wind erosion
- Salinization of soils
- Crusting and/or compaction of soils
- Water salinity buildup
- Brush invasion
- Aquifer depletion: subsidence
- Microclimate changes; deteriorated air quality
- Changing economic base
- Loss of farm and rangeland

RESPONSES:

- Major land rehabilitation measures
- Land use: optimized vs. maximized use
- Innovative management and technological procedures
- Conservation measures

Source: Modified from WESTPO, 1981.

remedial and adaptive measures are in general long-term, costly, and sometimes drastic; and finally, the affected biota have few or no mechanisms to recover from it.

The impact of humans on the "drying-up" of environments is indicated, at least in magnitude, by comparing data collected in 1882 and 1952. In those 170 years inaccessible forests throughout the world declined from 43.9% to 21.1% of the total terrestrial area, while deserts and wastelands increased from 9.4% to 23.3% (Ehrlich and Ehrlich, 1972).

Deserts themselves are not the sources from which desertification springs. Except for hot winds, the deserts supply none of the essential forces for the processes described. Desertification breaks out, usually at times of drought stress, in areas of naturally vulnerable land subject to the pressures of land use. These degraded patches link up to carry the process over extended areas. As the patchwork grows, it can eventually join with the climatic desert, and the final result will look exactly as if the desert itself had spread. The deserts extended in this way form wastelands over areas that from a strictly climatic point of view should not be entirely desert. It is generally incorrect to envision the process as only an advance of the desert borders engulfing usable land; the advancing sand dune is in fact a very special and localized case and a popular misconception of desertification.

To the extent that desertification contains self-reinforcing elements, its effects may extend outward through a whole system of climatic and land-use belts. As arid pastureland turns into complete desert, neighboring semiarid land once suitable for rainfed cropping may deteriorate into arid pasture. But since the process does not spring from the desert cores, it need not always work outwards, and the semiarid or subhumid cropland may be the first to deteriorate to desert status.

In its initial stages, desertification may merely involve a shift to a less productive ecosystem with water, energy, and nutritional balances less favorable to plant growth than before. As the situation worsens, the costs for controlling the process increase. The importance of desertification may be realized when the value of the losses produced by it are computed. For example, it has been estimated that it would cost $4 billion per year to replace the nitrogen and phosphorus nutrients lost to erosion (NRC, 1976). It is also essential to consider that during the last 100 years the world has lost 25% of its soils to erosion, and 200 to 300 thousand hectares of arable land are lost to salinization and waterlogging yearly. Desertification may cost up to $16 billion annually in lost agriculture production, of which almost $7 billion can be attributed to range and pastureland deterioration (Aspen Institute, 1978).

### 4. Purpose of Assessment

The main purpose of this study is to provide a holistic overview of the trends in land quality changes brought about principally by human intervention in the U. S. dry domain. This assessment is the first intergovernmental and multidisciplinary effort aimed at broadly assessing the extent to which desertification has or is occurring in the seventeen Western States, and to describe current efforts to arrest and prevent it. The document draws heavily on available, reliable, and accepted information on desertification which has been summarized; a preliminary analysis of the current situation is presented. Throughout this assessment, one aim has been to identify information and data required to adequately describe and locate present or potential high-risk areas, and to draw inferences on research needs which may not have been adequately addressed.

Discussions of the natural setting of the concerned locale, desertification processes and manifestations, methods of measuring it, and the procedures, capabilities, and programs available to combat the process are presented.

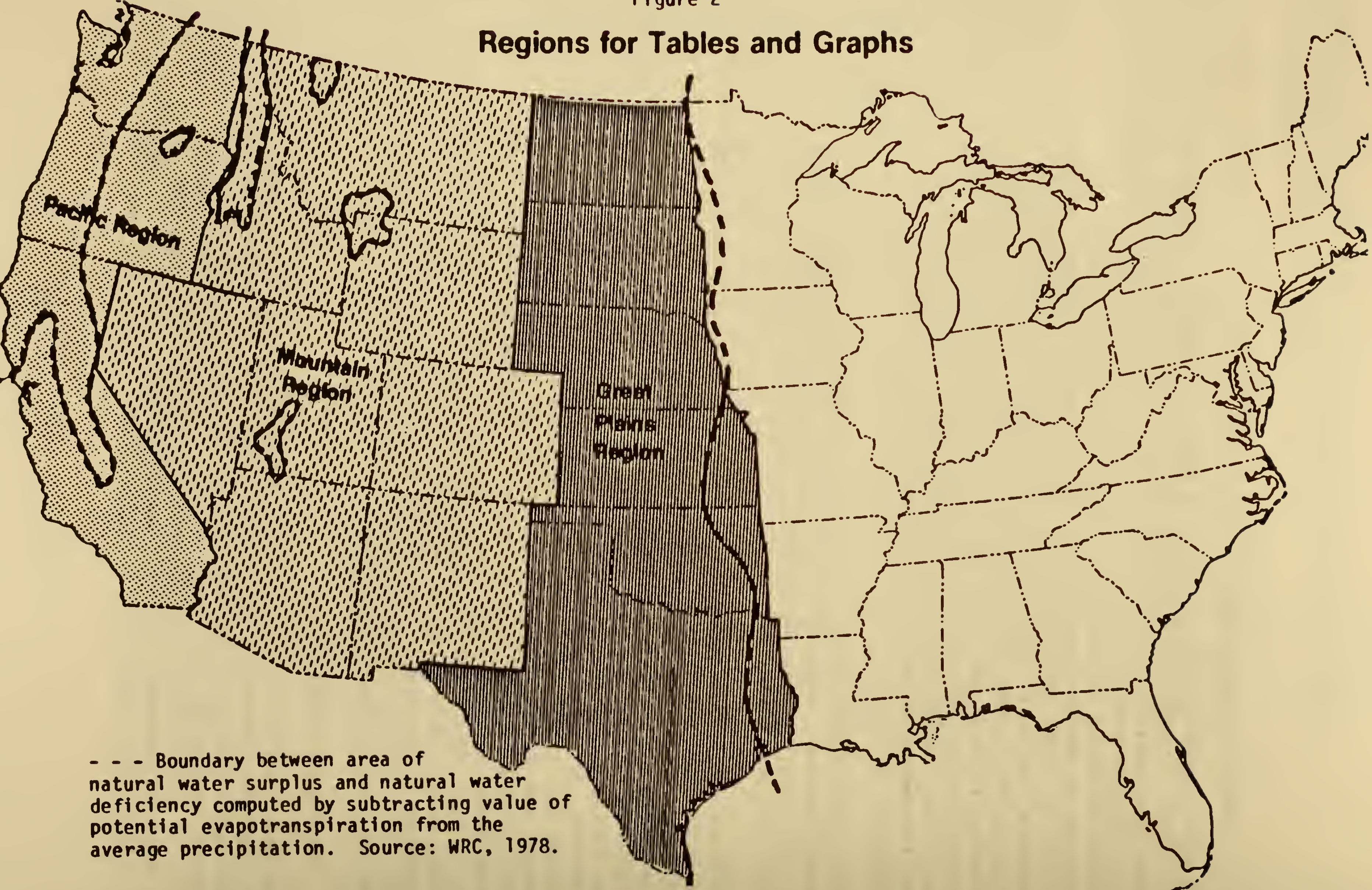
The focus of this assessment is on desertification induced by human activity, where the rate of change may be rapid, and where the resilience of the natural systems and the quality of the resource base may be diminished or wasted. Although considerable and detailed data exist for the specific conditions of the resource base (soil, water, vegetation, air quality, wildlife, crops, livestock, etc.) the total impact of human activity on the dry systems need to be understood and measured. As more people put greater demands on decreasing land resources, a thorough understanding of these impacts becomes increasingly important. The broad locale for this study covers the arid and semiarid regions of the 17 Great Plains and Western States where annual losses of water exceed annual water gains and considers all types of lands regardless of ownership. See figure 2, in which the States are also included in a regional classification generally accepted and used by officials and specialists.

### B. Natural Background

The deserts of the world have predictable locations. Those with the highest temperatures lie between about 20 and 35 degrees north and south latitude. They also occur on the leeward sides of mountain ranges and cold ocean currents. In contrast, the windward sides of mountains and the leeward sides of warm ocean currents may be areas of increased precipitation regardless of their latitudinal positions. Thus, deserts are generally zonal in their occurrence,

Figure 2

Regions for Tables and Graphs



- - - Boundary between area of natural water surplus and natural water deficiency computed by subtracting value of potential evapotranspiration from the average precipitation. Source: WRC, 1978.

but may vary in position due to the disruption of meteorological pattern by landforms and ocean currents. (For description of geographical regions, see Appendix D.)

### 1. Climate

In the United States the southern-most States lie in latitudes associated with desert formation; the climate of the States east of the Mississippi River however, is modified by the Gulf of Mexico, which provides abundant moisture. The precipitation pattern of the Westen States, on the other hand, is greatly modified by mountain ranges. The coast ranges (the Cascade, Wasatch, and Rocky Mountain systems together with the lesser mountain ranges in the Basin and Range Province ) all influence precipitation. As a result, there is a general tendency for precipitation to increase from south to north in the West, and for the rainfall to increase with elevation. Rainfall on the eastern sides of mountains, however, tends to be less than that on the west. Rainfall patterns are variable.

Along the West Coast precipitation occurs during the winter and early spring. A similar winter-spring maximum prevails across the middle and northern States as far as the Rocky Mountains. East of the Rocky Mountains the maximum seasonal precipitation occurs during the spring and summer. In the arid regions of Arizona and southern Utah there are two seasons of precipitation: December to April and July through September, with the summer season providing the largest amount. In contrast, the New Mexico maximum tends to be in the spring and summer. East of the Rocky Mountains the influence of the Gulf of Mexico is such that lines of equal precipitation run north and south and show an increase in precipitation in an easterly direction. Finally, moving to the north, while at the same time rising in elevation, the winter-spring precipitation tends toward snow, and temperatures decrease as do evaporation rates. Thus, in general, precipitation is more effective in these regions.

The net result is that the lowest amounts of precipitation in the United States (from 2 to 3 inches - 51 to 76 mm) are in the low valleys to the east of the Sierra Nevada in California, Nevada, and western Arizona. Moving eastward through the Basin and Range (physiographic) Province, precipitation increases to about 6 inches (152 mm) in the valleys in southern New Mexico. The minimum valley precipitation for Utah is about 6 inches (152 mm) as well. Every State west of the 100th meridian has areas with greater than 20 inches (508 mm) of precipitation. Between the Sierra Nevada and the Rocky Mountains these areas are found in the mountains.

Precipitation of local importance comes from tropical cyclones or low pressure centers which break upon the west coast of Mexico and may reach the Colorado Plateau. These storms travel inland along the valleys of the Basin and Range Province.

Practically all of the desert areas have temperatures that reach at least 105°F (40.6°C). The low temperatures of the intermountain region are less than those of the Great Plains for the same latitude. Freezing temperatures are found everywhere in the region; however, their frequency is highly variable. In addition, the number of days between killing frosts decreases from south to north and with elevation.

The temporal and spatial variations of climate of the American deserts are very great. The weighted mean annual precipitation of the United States east of the Mississippi is about 43.5 inches (1,100 mm). The maximum departure from this mean of the moving 10-year weighted average precipitation is about ±2 percent. The weighted mean annual precipitation of the area between the Rocky Mountains and the Mississippi River (including Montana) is about 28 inches (700 mm).

In this case, the 10-year moving average ranges from about 108 percent to 92 percent of this mean. The same comparisons for the area between the Pacific Coast and the Rocky Mountains show means of about 18 inches (450 mm) and variations of about 110 percent to 92 percent of the 10-year moving average.

In the true desert areas, annual precipitation for a given point may vary from more than twice to one-fifth the annual mean. Spatial variations are also very great. A difference of 10 inches of precipitation may be observed in less than 10 miles as a result of differences in elevation. Windward slopes receive more precipitation than leeward slopes. Because topography affects thunderstorm activity, large variations in the amount and intensity of precipitation can also occur over short distances in the summertime.

Thus variation in precipitation and temperature is a characteristic of the "American Deserts." Permutations and combinations of these variations are directly related to many problems associated with human activities in such arid zones. However, our ability to discern this association is obscured by our period of observation of these phenomena, which is limited to about 100 years. The only certainty in this short record is that new extremes continue to be set; hence there is little assurance that the frequency and magnitude of favorable and unfavorable combinations of weather have been established. (See Appendix F for further discussion of climate.)

### 2. Geology and Soils

The dry domain in the United States occupies all of the Basin and Range, Colorado Plateau, and Wyoming Basin (physiographic) Provinces; the western part of the Great Plains Province; part of the Columbia Plateau Province; the lower elevations of the Rocky Mountain Province; the southern part of the Central Valley of California; and the southern portion of the Pacific Coast Province. The first and last three of these provinces are essentially groups of long mountain ranges separated by valleys whose streams may or may not flow into an interior basin. They are all warm and temperate deserts and semideserts. The other provinces are underlain by relatively flat-lying rocks of a sedimentary and volcanic origin.

The productivity of the soils developed on the sedimentary rocks varies greatly. (Soils are also discussed in Appendix G.) Many shales are relatively saline, containing sodium salts. The soil particles of such soils are dispersed.

Consequently many areas are naturally relatively infertile. In addition, many of the sedimentary formations are easily erodible, resulting in high sediment loads transported by streams. Sequences of sedimentary formations also have an impact on stream behavior. Areas of hard rock lying above shales, for example, produce relatively high discharges on the valley bottoms. Less porous rock surfaces also retard water absorption resulting in concentrated runoff of surface water, which in turn may also lead to increased channel erosion.

The complexity of dry regions in the United States is demonstrated by the Basin and Range Province which extends from Oregon to Arizona and New Mexico. Geologically the Basin and Range Province is a series of fault blocks which have been eroded into mountainous segments, with debris deposited in the adjacent valleys. Prominent mountain blocks are elongated and run in a general north-south direction.

The debris derived from these mountains originates through the effects of temperature variation and wind action. The size of the debris diminishes downhill so that the material that reaches those parts of the valley with the lowest slope is very fine. The characteristics of the debris on the intervening slopes depend upon precipitation and temperature. 'In other areas the debris may be a simple mixture of sizes. In either case the fine material on the surface tends to be blown or washed away, leaving an exposed layer of coarser material know as an erosion pavement.

Given an intermediate amount of precipitation, a residual soil may be developed in the upper layers of these fine deposits. The drainage network of the Basin and Range is usually represented by a series of small streams entering a linear system. The discontinuous nature of the precipitation is such that water rarely is contributed by all of the small basins at any one time. Thus, the debris contributed to the major drainageway is highly variable in size. Although most of the debris deposited in the main valley is small in size, there is always enough local coarse material for some of the runoff to move underground as groundwater. Groundwater quality may be highly variable, being dependent on the quality of the valley alluvium.

Erosion of the mountain slopes and deposition on the valley floors is a natural geologic process. However, because the deposition from the side slopes is concentrated by tributaries at irregular intervals on the valley floor, the slope of the main stream is not uniform. Areas of excessive deposition have over-steepened slopes which, under high discharges, are unstable. Frequently valleys have local steep areas of erosion marked by discontinuous gullies. If these gullies become connected with a continuous channel, the process is extremely difficult to reverse. No activity that inhibits the movement of sediment can cause a gully to refill downstream.

Variability is the main characteristic in the Basin and Range Province. Infiltration rates by runoff are extremely variable. Rates are nil on solid rock, low on deposits of very fine material, and high in mixtures with coarse material. The relationships of the small basins to the main stream are also highly variable. Some contribute to the major drainage, while others spread on the valley floor, sometimes forming alluvial fans. In other instances, water may not even be contributed to a stream system.

From a geological perspective, two conclusions are important. First, that the natural climatic cycles of wet/dry precipitation periods dwarf the fluctuations known in human recorded history. Secondly, that the dry areas of western North America are relatively young, roughly one-fourth the age of other dry regions of the world. These conclusions have a direct relationship to the diversity of flora and fauna nature to our arid regions, as well as man's role or influence in the desertification process.

### 3. Vegetation

Many plants have particular growth requirements in arid zones. Among these are seasonal moisture, temperature, and exposure for germination to occur. To continue growth, conditions must be favorable throughout the growing season. After the first year, a perennial plant has built up a food reserve that permits survival under adverse conditions. Continued unfavorable conditions, however, will eventually result in plant disappearance.

Vegetation in drylands may be divided into three general types: 1.) plants that are dependent on local precipitation alone; 2.) vegetation dependent on local rain accummulated in depressions and drainage courses; and 3.) plants that depend on sources outside the system, e.g., irrigation or rivers or lakes fed by rainfall elsewhere (Cloudsley-Thompson, 1977).

Arid lands plants are adjusted to climatic conditions by having structures that minimize transpiration and a skin that resists damage by windblown sand. As precipitation increases, the leaf area in succulent plants increases in size as water is stored. Where winter and spring precipitation is dominant, the vegetation tends toward shrubs and trees. In areas of summer precipitation, the tendency is toward grass. With low precipitation, either winter or summer, the bulk of the vegetative cover consists of annual plants with rapid life/reproductive cycle.

In the range alone, an array of 54 ecosystems can be found formed by grasslands, shrublands, and coniferous and deciduous forests. In the Pacific Coast area, the rangeland ecosystems are characterized by annual grasses, bunchgrasses, sagebrush, chaparral, and mountain meadows while the forests are primarily coniferous. The arid and semiarid ranges of the Southwest and the Intermountain Great Basin area are dominated by a complex of bunchgrasses, annual grasses, cacti, salt-tolerant shrubs, sagebrush, pinyon-juniper, and chaparral. A mosaic of sagebrush, grasslands, meadows, aspen, and conifers makes up the rangelands and forests of the Rocky Mountains. East of the Rockies are the Great Plains ecosystems characterized by short grasses and midgrasses and low shrubs on the western part of the plains, and by tall grasses, shrubs, shinnery, and savanna on the eastern edge. East of the 95th meridian, forest ecosystems dominate the landscape with only remnants of prairie and wet grasslands (RPA, 1980). (For further information on vegetation, see Appendix E.)

### 4. Biological Change and Climate

Fluctuations in wet/dry cycles and corresponding temperature patterns are reflected in the dynamics of plant populations. Short-term trends (seasonal to as much as a decade) are generally expressed in the survival of individuals of a species or the reproductive success of a species' population. Long-term trends (scores of decades to centuries) are expressed as changes in the geographic distribution of a population, which can result in changes in the vegetation type at a location or in the composition of plant associations. All native wildlife of our arid regions respond directly or indirectly to the dynamics of plant distribution and abundance. Aquatic species are obviously limited in arid regions and represent an exception to this generality.

The sporadic availability and generally disjunct occurrence of surface water results in both low diversity of aquatic animals and the evolution of many unique life forms. Terrestrial life in the "dry domain" is highly diverse in both plant and animal species. At the present time, only a few large species of animals actually live under the continuous rigors of the desert climate - man, his domestic animals, and natives such as the pronghorn and desert bighorn. The vast majority of desert wildlife species are but a fraction of this physical size, and thus can find living conditions quite different from those of the general climate (Schmidt-Nielsen, 1964). For example, many bird species occupy desert areas only for a portion of the year, when conditions provide abundant food and moderate temperatures. These species migrate elsewhere during the severe climatic periods. Most small mammals, reptiles, and invertebrates are full-time residents, but escape the stressful periods of temperature and accompanying restricted food and water availability through a variety of behavioral and physiological means (Bartholomew, 1964). Most plant species of arid regions show a similar pattern of adaptation. For example, annual plants (forbs, including wildflowers) only grow during seasonal periods of moderate temperatures and high soil moisture; most arid region shrubs and trees respond similarly.

Many woody plants have evolved mechanisms for capturing and storing moisture from the sporadic precipitation. Some important shrubs (phreatophytes, like mesquite) have extensive tap roots, which "mine" groundwater tables many feet below the surface.

### 5. Biological Diversity and Evolutionary Change

The "dry domain" of the United States owes much of its biological diversity to topographic diversity and the consequent diversity of micro-climates. On a broad regional scale, we find "islands" or remnant areas representing biological communities persisting from prehistoric periods of moister climates (Axelrod, 1950). For example, certain mountain tops in the Mojave Desert have relict stands of forests (coniferous trees, live oak) that are separated by hundreds of kilometers from similar current vegetation types. These areas also support unique species of wildlife. Around water or along water courses, riparian vegetation and accompanying wildlife also exist as islands or ribbons. These relict islands and ribbons are the key to the great diversity of wildlife utilizing the dry domain. These areas are also the most sensitive to both natural and artificial changes that lead to desertification.

The comparative youth of the dry domain in this country (Schwarzbach, 1961) has a bearing on the sensitivity of wildlife and their habitats to desertification. A general feature of biological evolution is that species adaptations to a specific environment will increase in proportion to the geologic age of the environment. In addition, species with short life spans, or those which produce large numbers of reproductive units (seeds or eggs), will adapt more quickly to stressful environments. Thus, essentially all plants and invertebrates that inhabit the dry domain exhibit some degree of specialized adaptation to desert conditions. However, due to the relative youth of desert conditions, higher vertebrates (birds and mammals) exhibit comparatively few specializations to the dry domain of the western United States. As an example, sub-Saharan Africa has a number of seed-eating bird species that can survive extended periods without drinking water. The dry domain of the United States has evolved only one such species, the Black-throated Sparrow (Smyth and Bartholomew, 1966). Thus, it can be suggested that any major increase in the rate of desertification whether natural or man-caused, will have a relatively greater impact on higher vertebrates than on other biological components.

### 6. Ecological Function

The dry domain contains a wide variety of ecological systems, and these arid ecosystems have some special structural and functional properties which form the basis for exploitation by both wildlife and humans. Primary productivity (new plant material, or biomass, generated each year) is third highest among the world's major land biomes, exceeded only by grasslands (including savannas) and tropical forests (Kormady, 1969). Yet deserts rank the lowest of the major biomes in accumulation of biomass, and the bulk (91%) of what is there is unavailable as litter or below-ground roots. In addition, decomposition in deserts recycles nutrients for plant growth very slowly. This underscores the fragile balance that occurs between production, available harvest, and the recycled material required for maintenance of productivity.

(Appendices D, E, and F provide descriptive geographical and ecological material and further discussion on droughts, floods, albedo, and climate variability and changes).

## C. Historical Perspective

Occupancy and development of the Western drylands attended by cycles of drought and boom and bust brought penalties such as soil erosion, overgrazed ranges and overcut forests, recurring floods, settlement of unsuitable land, farmland abandonment and fleeing settlers, and even stranded communities. The Dust Bowl and Depression of the 1930's brought forward a whole array of remedial measures including soil conservation programs, public land grazing controls under the Taylor Grazing Act, shelterbelts, natural resource and land-use planning, purchase and retirement of marginal farmland, agricultural stabilization efforts, passage of the Water Facilities Act, and crop insurance.

With all that has happened, the West, with its sunbelt; growing population; stores of energy resources; generally productive agriculture, spacecraft and aviation, electronic and computer, and defense-related industries; and outstanding recreation attractions; is now the Nation's most dynamic region.

There are five major uses of land in the 17 Western States. These include farming, grazing, energy development, urbanization, and recreation.

It is well to emphasize before proceeding that none of the described land uses and attendant management practices is considered per se causative of desertification and that the degradation of natural resources, in many instances, may have been the product of lack of knowledge or failure to adopt necessary safeguards.

### 1. Farming

The human activity with the most profound impact on the lands of the West has been agriculture. In 1974, 26 percent of the land area was in cropland, and another 59 precent in privately-owned pasture and rangeland.

Succeeding waves of settlers, numbering in the hundreds of thousands, moved West to the mid- and short-grass prairies and plains and beyond to the Oregon Country, the intermountain basins, and the great valleys of California. They claimed land under the Homestead Acts, and in many places erected barbed wire fences and plowed the open range. By 1860, 3 to 4 million acres were under cultivation in the Plains States. The great boom into the Great Plains began in the late 1870's, and by 1900, 69 million acres (28 million hectares) were cultivated, aided by agricultural mechanization such as the McCormack reaper. By 1929, there were almost 194 million acres (79 million hectares) in cultivation, and 30 years later there were 217 million acres (88 million hectares). Now about 200 million acres (81 million hectares) are under cultivation.

Various generalizations are in order about agriculture in the 17 Western States. There has been an enormous increase in production despite reductions in cultivated acreage, number of farms, and numbers of farmers and farm workers. The average farm in the West is much larger than in the rest of the country. There is more specialized farming, and a greater variety of crops is raised. Farming costs have climbed steadily since the early 1950's, while farm commodity prices have been on a roller coaster during most recent periods. Although western agriculture has moved forward with the rest of the economy, at the moment it seems to be declining in importance in relation to manufacturing and mineral resource development. But, short- and long-term world and national farming realities point to rising demands for western grains and livestock products.

### 2. Grazing

A major economic use of the semi-arid and arid lands of the West is grazing of domestic livestock, on about 85 percent of the rangelands in both private and public ownership. There were 399 million acres (161 million hectares) (65 percent of the total rangelands) in nonfederal ownership in the 17 Western States in 1977. This compares with 212 million acres (86 million hectares) of Federal rangeland, mainly administered by the Bureau of Land Management and the Forest Service. A smaller portion of the acreage is administered by the Bureau of Indian Affairs, National Park Service, or the Department of Defense (RPA, USDA, 1980). Grazing on Federal range has become of major importance to the livestock industry in the 17 Western States. This is especially so in the 11 States in the Rocky Mountain and Pacific Coast regions, where 90 percent of the Federally-owned grazed lands are located. It has to be noted that 53 million acres of pastureland in private ownership throughout the 17 Western States also serve the livestock industry.

Domestic cattle and sheep graze on almost two-thirds of the public rangelands of the Western States on a seasonal basis, and multiple-use planning and monitoring determine the amount of vegetation available for each of the various consumptive users of the public rangelands, including livestock. The sheep industry is especially dependent upon Federal grazing lands, which provide over two-fifths of their annual forage requirements. The cattle industry is generally less dependent upon Federal land, but the relationship between public and private land sources of feed is usually very important to the local beef cattle industry.

### 3. Energy Development

Energy development in the western United States has been a constant part of their history, but now it has entered an era of extensive activities of particular importance with U.S. policy emphasis on energy self-sufficiency. The uniqueness of ongoing development resides in the extraordinary economic growth of the region, in the changes of traditional land uses, lifestyles, size and character of communities, support systems, and the landscape.

The impacts of energy development are: a) the physical impacts produced by mining and processing the ores and the disposal of waste material, b) the consequences of these operations on surface and ground water, and c) the attendant socio-economic community growth and change.

Until recently, most approaches to rehabilitation of mined and mine-disturbed land have been fragmentary and have not been approached from an ecological perspective. Nonetheless, significant progress has been made in rehabilitating disturbed land and extensive research is being carried out in this field today.

Because the economy and ecology of the arid and semi-arid West is so dependent on water availability, it is necessary to ensure that energy development proceeds in a manner that protects the region's water resources. Changes in quality of life resulting from rapid growth problems can sharply escalate the costs and time required to complete the energy projects. Identification and solution of community problems become a cost that is part of the full expense of reaching social benefits from new energy production.

### 4. Urbanization

By 1960, the 11 Western States had a population of 27.2 million people. The census of 1970 counted 34.8 million. A forecast for the year 2000, based on trends to 1970, indicates a doubling of population to 68 million.

An example of the rapid urbanization in the Western States is occurring in the Front Range area of Colorado. Today the population of the area is 2.5 million (86 percent of the State population). In the next 20 years, the population is expected to increase to 3.8 million (88 percent of the State population). In the last 20 years, 1,766,000 acres of agricultural land in the Front Range has been converted to other use. In the next 20 years, land conversion is expected to take the space equivalent to a 10 mile wide strip stretching from Denver to Colorado Springs (approximately 384,000 acres). Water presently in urban use in the Front Range exceeds 540,000 acre/feet annually. In 20 years, a total of 829,000 acre/feet will be needed annually.

### 5. Recreation

Public recognition of recreational values has grown rapidly in recent years. Increased leisure time, mobility, and accessibility have accelerated public participation in this kind of activity and such use is expected to increase. In 1977, over $11 billion was received for amusement and recreational services, with construction of buildings for social and recreational purposes that year amounting to $3.5 billion nationwide (U.S. Dept. of Commerce, 1978). In general, a very large share of these activities take place in the Mountain, Southwest, and Pacific regions. Many of these recreational activities take place in publicly owned recreational services, including state and local parks and the National Park Service sites. The Bureau of Land Management alone administers 326 recreational sites covering 12,196 acres and having an estimated 58,308,000 visitor-days use in 1976, mainly in and from the Western States.

In order to make better use of the recreational opportunities available throughout the arid/semiarid areas of the country, better measurement techniques for dispersed recreation activities need to be developed to identify types of use, expectations, and behavioral patterns of dry environmental/ecological changes and recreation activities/use patterns; the relationship between values and uses, and possible conflicts; and the relationship among users from a human ecology perspective (Innis, 1978).

## D. Desertification Processes and Manifestations

Desertification is the result of various ecologic changes that lead to soil depletion by erosion and nutrient losses, impoverishment of the vegetation and dependent animal life, salinization and waterlogging of irrigated and non-irrigated lands, degradation and exhaustion of water resources, and impairment and spoliation of land surfaces. Desertification may be spread by human means along a desert edge, but far more generally it happens in patches in arid, semiarid, and even subhumid regions, reducing the quality and productivity of these lands.

The processes that contribute to desertification and their manifestations will be discussed individually, but will be presented in three general groups: (1) biological resources; (2) soils; and (3) water. The changes in the amount and quality of vegetation, with a special discussion on brush infestation, animal population changes, and the declines in yield observed when desertification occurs, compose the first group of processes and manifestations examined. Erosion, nutrient loss, compaction, crusting, and soil salinization are presented in the second group. The last discusses waterlogging, water salinity buildup, and sedimentation problems. (Water information is also presented in Appendix H.)

### 1. Biological Resources

#### a. Vegetation Changes: Quantity and Diversity

Induced and extensive losses of plants may result in a self-reinforcing desertification process, with the land's ability to continue with a steady production of vegetation impaired or even lost.

Depletion of vegetation reduces the plant population and soil protection, and alters the nutrient and hydrological cycles of the area. The amount of litter, mulch, and microbial and animal activity diminishes, and the amount of nutrients returning to the cycle decreases, thus impairing the sustained normal plant growth and production.

Loss of the vegetation affects the soil quality and increases the reflectivity of solar radiation (albedo). This is considered by some climatologists to intensify desertification in semiarid/arid areas. One reason for erosion beginning after vegetation loss is the decline of root structure which conserves moisture and holds the soil. As a result, flooding can also occur which further damages the soil, plants, and animal life. Loss of property and life can and does result.

The loss of perennial shrubs, trees, grasses, succulents, lichens, and annuals is serious for several reasons. They hold down wind velocities and so decrease both evaporation and wind erosion, and provide small shelter and feed oases in which animals and weaker plants can survive drought to recolonize the areas between the shrubs when the good years return or after excessive use ceases. When desertification is on-going, the quality of the plant population and the number of varieties of desirable perennial vegetation species is reduced. In general, a declining ecosystem is not able to support the complexity of species it would support at the climax state.

When sound management is applied, the species diversity may actually increase by opening up the community and creating more and different habitats. Increased production is characteristic of the early successional stages. The comparative youth of the "Dry Domain" in this country has a bearing on the sensitivity of the ecosystem to desertification.

### b. Brush Infestation

"For years conservation district leaders have identified brush encroachment as one of their biggest conservation problems." They point out that noxious and undesirable woody plants "reduce production of food and fiber, accelerate erosion, unnecessarily waste water, and in many places degrade wildlife habitat." (Pendleton, 1979). The optimum situation for livestock and wildlife is a diversity of grasses, forbs, and brush.

Brush is defined as woody half-shrubs, shrubs, and trees that invade land on which they are not part of the potential natural (climax) plant community or occur in amounts significantly in excess of that which is natural to the site. Species listed as brush often have desirable qualities, especially for wildlife. Nevertheless, they are listed as brush because of their tendency to create resource management problems by interfering with intended land use and multiple-use management (USDA, RCA 1980). The most frequently mentioned serious woody pests in a 1973 Soil Conservation Service (SCS) brush survey were oaks, junipers, sagebrush, cactus, rabbitbrush, mesquite, and acacias.

#### Classification

In the 1973 Survey, brush was categorized as sparse, medium, and dense, defined as follows:

Sparse - Woody plants are present in amounts not in excess of that in the potential natural plant community for the site. They do not significantly suppress growth of other vegetation nor interfere with normal use of the land. Control measures are not usually needed or recommended.

Medium - Woody plants are present in somewhat greater amounts than is normal for the site, suppress growth of more desirable plants, and seriously limit the use of the area. The stand or acreage will increase unless counter-measures are taken. Treatment, though not yet critical for soil protection and forage production, is usually desirable.

Dense - Woody plants are present in amounts considerably exceeding that which is normal for the site, dominate the plant community, seriously suppress growth of more desirable plants, or severely restrict the use of the land. The plant cover does not provide adequate protection against soil erosion. Corrective measures are needed, and some kind of treatment is necessary.

Based upon the percentage of grazing land covered by dense and medium stands of brush, SCS recognized four levels of brush problem, as follows:

| Degree of problem | Percent of grazing land covered by dense and medium stands of brush |
|---|---|
| None to slight | 0-10 |
| Moderate | 11-25 |
| Major | 26-40 |
| Severe | over 40 |

According to this rating system, USDA compiled Figures 3 and 4. These ratings are on a statewide basis, and do not pinpoint the severity of the brush problem at specific locations (USDA, RCA, 1980). The degree of brush infestation is considered to be similar on Federal and non-federal lands.

While biomass production increases, this encroachment of brush and weeds may significantly reduce the livestock production of range. To illustrate, the infestation of mesquite in 130 counties in West Texas reduced forage by 0.9 to 1.8 million animal-unit months 1971 (Osborn and Witkowski, 1974). The value of the forage thus lost is estimated at between $4 and $8 million per year.

Brush management activities have been successful in reducing the overall density of the brush stand, but not in reducing the total acreage (USDA, RCA, 1980). This indicates that the brush management activities have been directed at dense stands where brush is dominant in the plant community, seriously suppresses growth of more useful plants, and severely restricts the use of land (Pendleton, 1979). Eradication is rarely a planned objective of brush management, and it is economically, ecologically, and technically infeasible (USDA, RCA, 1980). The use of the herbicide 2,4,5T, considered effective in brush control, is permissible on rangeland under EPA regulations if under the supervision of a certified applicator, but use has been temporarily suspended on pasture land until further clarification of the regulation. The removal of brush may lead to some enviromental problems. For example, removal by mechanical means such as chaining may disturb other vegetation as well as animals, and if not practiced with the proper safeguards, may cause at least a temporary acceleration of soil erosion.

### c. Changes in Animal Population

Desertification in any part of the dry domain generally reduces the site's forage production, increases the soil susceptibility to erosion (Branson et al., 1972), and alters the amount and types of shelter available. When such deterioration occurs, the local animal population is affected, especially the higher vertebrates (mammals, birds). This applies also to the introduced domestic animals and their feral descendants. The use of rangelands by the livestock industry has motivated the keeping of records and the

Figure 3: Brush on Federal and Nonfederal Land (1973)

- Percentages -

| Region | % of Total Grazing Land Covered by Brush | | % of Grazing Land in Medium and Dense Stands of Brush | |
|---|---|---|---|---|
| | Federal | Nonfederal | Federal | Nonfederal |
| Great Plains | 52 | 57 | 74 | 74 |
| Mountain | 53 | 53 | 53 | 50 |
| Pacific | 59 | 59 | 52 | 53 |

Source: USDA, RCA, 1980.

Figure 4:

## Acreage of Brush on Nonfederal Pastureland and Rangeland, by State, 1963 and 1973

| | Total | | Medium Stand | | Dense Stand | |
|---|---|---|---|---|---|---|
| | 1963 | 1973 | 1963 | 1973 | 1963 | 1973 |
| Arizona | 17,000,000 | 18,239,000 | 4,080,000 | 4,100,000 | 4,930,000 | 5,086,150 |
| California | 11,300,000 | 11,210,000 | 1,930,000 | 1,900,000 | 4,470,000 | 4,410,000 |
| Colorado | 8,500,000 | 7,927,000 | 1,700,000 | 3,170,000 | 5,525,000 | 2,378,100 |
| Idaho | 4,949,800 | 4,984,800 | 1,236,700 | 1,246,200 | 2,473,400 | 2,492,400 |
| Kansas | 3,600,000 | 4,100,000 | 900,000 | 1,025,000 | 1,260,000 | 1,640,000 |
| Montana | 15,100,000 | 15,000,000 | 3,775,000 | 3,750,000 | 4,530,000 | 4,500,000 |
| Nebraska | 375,000 | 300,000 | 185,000 | 160,000 | 115,000 | 75,000 |
| Nevada | 5,615,000 | 5,380,000 | 575,000 | 400,000 | 240,000 | 190,000 |
| New Mexico | 23,000,000 | 23,815,000 | 5,750,000 | 7,144,500 | 3,450,000 | 4,763,000 |
| North Dakota | 7,000,000 | 7,000,000 | 785,000 | 790,000 | 430,000 | 450,000 |
| Oklahoma | 8,925,000 | 11,016,000 | 4,462,500 | 3,855,600 | 3,570,000 | 6,609,600 |
| Oregon | 6,848,000 | 5,972,000 | 5,136,000 | 3,881,800 | 1,027,200 | 895,800 |
| South Dakota | 103,210 | 106,550 | 14,450 | 14,920 | 1,030 | 1,060 |
| Texas | 93,389,000 | 91,825,000 | 28,016,700 | 30,302,000 | 56,033,400 | 39,485,000 |
| Utah | 7,573,000 | 7,004,000 | 3,029,200 | 3,151,800 | 3,407,850 | 2,801,600 |
| Washington | 5,000,000 | 5,200,000 | 600,000 | 500,000 | 300,000 | 200,000 |
| Wyoming | 23,500,000 | 22,700,000 | 2,350,000 | 2,724,000 | 6,580,000 | 4,994,000 |
| Total 17 Western States | 241,778,010 | 241,779,350 | 64,525,550 | 68,115,820 | 98,342,880 | 80,971,710 |
| Total U.S. | 278,667,460 | 277,441,775 | 82,575,015 | 84,854,925 | 103,361,350 | 91,511,465 |
| 17 Western States % of Total U.S. | 86.8 | 87.1 | 78.1 | 80.3 | 90.8 | 88.5 |

Source: SCS brush survey, USDA, RCA 1980.

undertaking of range management studies which provide some information on the condition of these lands through the time of utilization. In general it has been recognized that today the condition of the range is the best in this century, but that the damage done by excessive grazing prior to the turn of the century, is still largely present. The influence of topographic and diverse conditions of rangeland forage production in the dry domain is exemplified by Figure 5. According to Soil Conservation Service estimates, nonfederal range condition has improved considerably in recent years. (See definition of range condition in glossary.) They indicate that from 1963 to 1977, the percentage of range in excellent condition increased from 5 to 12 percent; range in good condition increased from 15 to 28 percent; range in fair condition increased from 40 to 18 percent. Furthermore, in 1977 range condition was improving in 13 of the 17 major range states, remaining static in three, and declining in one. Range condition varies greatly among States (See Figure 6).

Wildlife existing in the 17 Western States has been impacted over the years by settlement and changing land uses such as farming, livestock grazing, buildup of urban areas and transportation systems, mining, recreation, and other human endeavors. The difficulty in distinguishing between effects of desertification and of ecological changes due to development is compounded by the presence of feral animals that also compete for the resources of the land. Data on the quality of wildlife habitat is presented in figure 7.

With the passage of the 1971 Wild Free-Roaming Horse and Burro Act (Public Law 92-195) the Secretary of the Interior, through the Bureau of Land Management, was charged with the protection, management, and control of all unbranded and unclaimed horses and burros inhabiting public lands. Congress specifically states these animals are to be considered as an integral part of the natural system of the public lands and would be managed in such a manner as to achieve and maintain a thriving natural ecological balance.

The population density of wild horses and burros, like that of all other animals, must be in tune with and not exceed the carrying capacity of the available habitat. (Figure 8). Uncontrolled population growth may lead to overgrazing and desertification. In turn, large and small animals are affected by desertification, and although the latter consume only a small part of an ecosystem's production, they may suppress the vegetation on which they feed. A particular vegetation type does not usually change due to the feeding of small animals, but it may be held or maintained in one seral stage due to their feeding (Wagner, no date). Exceptions are degradations due to large populations of grasshoppers, locusts, prairie dogs, or rabbits.

Figure 5: Acres of Forage Land Per Animal Unit

| State | Total Animal Units (x 1000) | Total Nonfederal Forage Land (x 1000 Acres) | Acres of Nonfederal Forage Land Per AU |
|---|---|---|---|
| Arizona | 1,063 | 36,614 | 34.4 |
| California | 4,725 | 23,659 | 5.0 |
| Colorado | 2,378 | 29,956 | 12.6 |
| Idaho | 1,644 | 11,122 | 6.8 |
| Kansas | 4,368 | 21,147 | 4.8 |
| Montana | 2,489 | 46,862 | 18.8 |
| Nebraska | 4,461 | 28,599 | 6.4 |
| Nevada | 541 | 8,807 | 16.3 |
| New Mexico | 1,343 | 45,293 | 33.7 |
| North Dakota | 1,634 | 15,290 | 9.4 |
| Oklahoma | 4,176 | 27,361 | 6.6 |
| Oregon | 1,388 | 15,652 | 11.3 |
| South Dakota | 2,979 | 29,357 | 9.9 |
| Texas | 11,801 | 120,564 | 10.2 |
| Utah | 880 | 11,831 | 13.4 |
| Washington | 1,242 | 10,747 | 3.6 |
| Wyoming | 1,255 | 29,224 | 23.3 |
| Total 17 Western States | 48,367 | 512,085 | 10.6 |
| Total U.S. | 100,693 | 672,126 | 6.7 |
| 17 Western States % of Total U.S. | 48% | 76.2% | |

Source: USDA, RCA, 1980.

## Figure 6: Condition of Federal and Non-Federal Rangeland by State, 1976

| State | Extent (1000 Acres) | Condition - % | | | |
|---|---|---|---|---|---|
| | | Good | Fair | Poor | Very Poor |
| Arizona | 58,823 | 12 | 28 | 44 | 16 |
| California | 53,290 | 18 | 17 | 32 | 33 |
| Colorado | 35,228 | 12 | 30 | 41 | 17 |
| Idaho | 24,182 | 19 | 36 | 32 | 13 |
| Kansas | 16,278 | 10 | 45 | 34 | 11 |
| Montana | 54,156 | 16 | 40 | 35 | 9 |
| Nebraska | 24,274 | 15 | 31 | 35 | 19 |
| Nevada | 62,736 | 12 | 48 | 32 | 8 |
| New Mexico | 59,832 | 10 | 20 | 47 | 23 |
| No. Dakota | 12,296 | 33 | 35 | 23 | 9 |
| Oklahoma | 9,301 | 11 | 38 | 40 | 11 |
| Oregon | 24,804 | 19 | 38 | 30 | 13 |
| So. Dakota | 23,402 | 15 | 47 | 31 | 7 |
| Texas | 91,599 | 13 | 23 | 46 | 18 |
| Utah | 39,615 | 19 | 26 | 36 | 19 |
| Washington | 7,895 | 20 | 28 | 39 | 13 |
| Wyoming | 47,608 | 18 | 36 | 37 | 9 |

Source: U. S. Dept. of Agriculture/Forest Service, An Assessment of the Forest and Range Situation in the U. S., 1980.

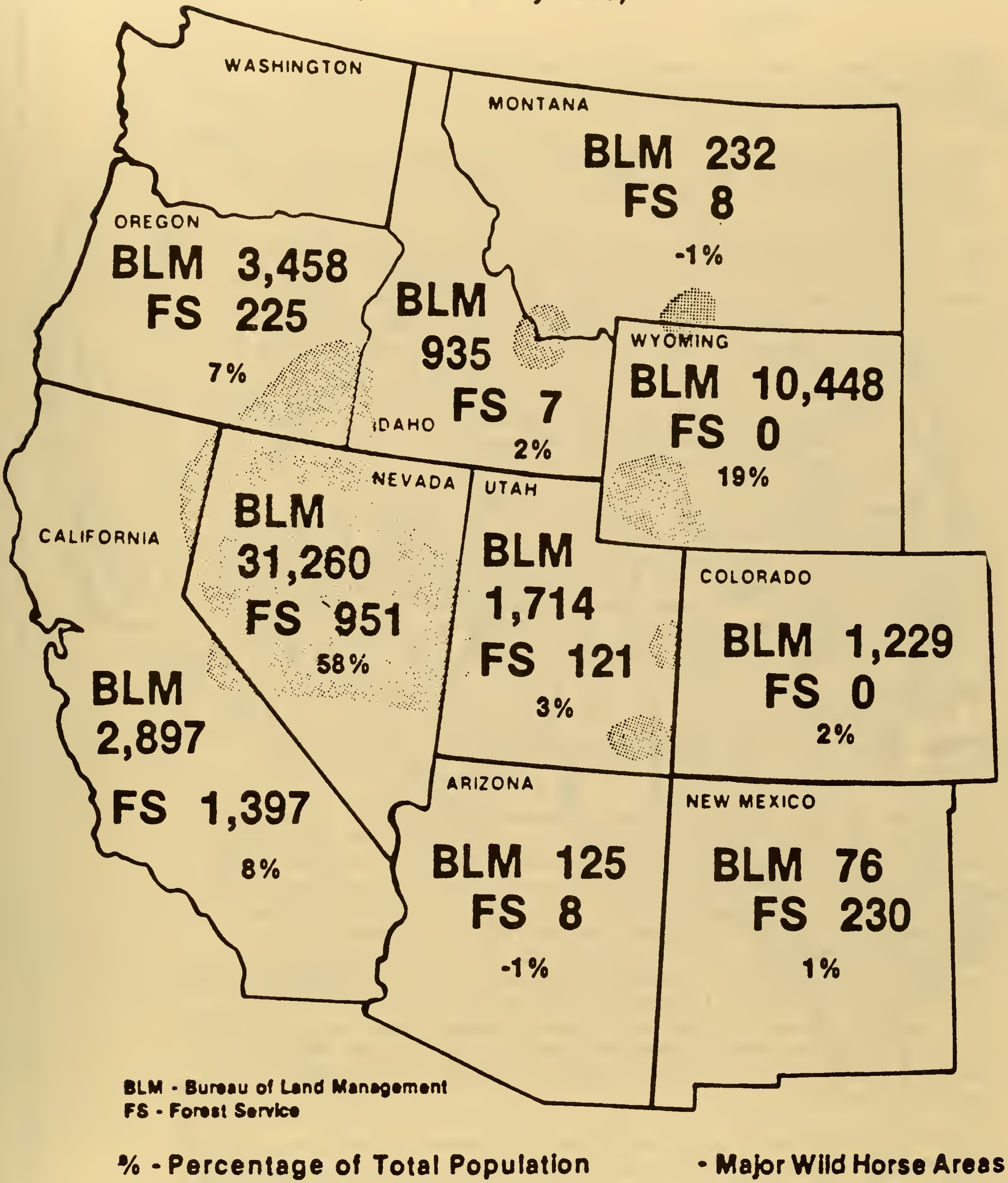
Figure 7: U.S. Wildlife Habitat Classification, 1975

(by % of total)

| Class of Wildlife | Improving | Static | Declining |
|---|---|---|---|
| Big Game | 8.0 | 59.5 | 32.5 |
| Small Game | 10.2 | 59.5 | 30.3 |
| Nongame | 10.5 | 57.2 | 32.3 |
| Fish | 22.7 | 64.8 | 12.5 |

Source: Bureau of Land Management, Range Condition Report, Prepared for the Senate Committee on Appropriations, January 2, 1975.

Figure 8 ESTIMATED WILD HORSE POPULATION
(as of January 1980)



Source: National Academy of Sciences, for BLM/FS, December 1980.

## 2. Soils

### a. Erosion

Erosion due to natural causes has been described in Section II B. The accelerated erosion due to manmade causes is briefly discussed here.

Today, this country loses 4 billion tons (3.6 billion metric tons) of topsoil every year at an estimated cost of one billion dollars (EPA, 1980).

It is estimated that nearly half of the sediment reaching the Nation's streams and lakes each year comes from agricultural land. Another 10 percent comes from range and forest lands, with 10 percent from eroding roadsides, construction activities, surface-mined lands, and other disturbed areas. The remaining 30 percent results from geological erosion. It is the 70 percent of erosion attributable to the activities of people, much of which carries with it other pollutants, that can be reduced or prevented through the application of conservation practices to the land (EPA, Water Quality Management Bulletin, 1980).

Accelerated erosion (figure 9) falls into two general categories--water erosion and wind erosion. The main part of the soil removed is the most fertile--the topsoil. This is followed by retrogressive changes in the system as the result of the artificial reduction of plant cover, with more soil exposed as a consequence. Most subsoils, being either poor in nitrogen and phosphorous, or heavily cemented, are more difficult to erode.

#### Water Erosion

Water erosion is usually termed "sheet and rill" erosion. See figures 10 and 11.

This type of erosion is particularly acute on the steep slopes of the wheat lands of the Palouse region of the Pacific Northwest and on the shale-derived soils of the Dakotas, Wyoming, Colorado, Utah, and New Mexico. Virtually every medium-to-fine textured cultivated soil having a slope greater than 1° is subject to water erosion. When slopes become as steep as they are in the Palouse country, good land management (such as strip farming) can retard erosion, but can keep it within tolerable limits only with difficulty. Sheet and rill erosion is also a major contributor to salt loading in Western streams. Soils high in salt content, such as marine shales, are great contributors and probably the largest diffused source. These salts are highly soluble and are concentrated in surface runoff.

Of the four billion tons of soil that are picked up each year by the Nation's streams, 25% of this total tonnage is discharged into the oceans. The other 75% is moved around within drainage basins.

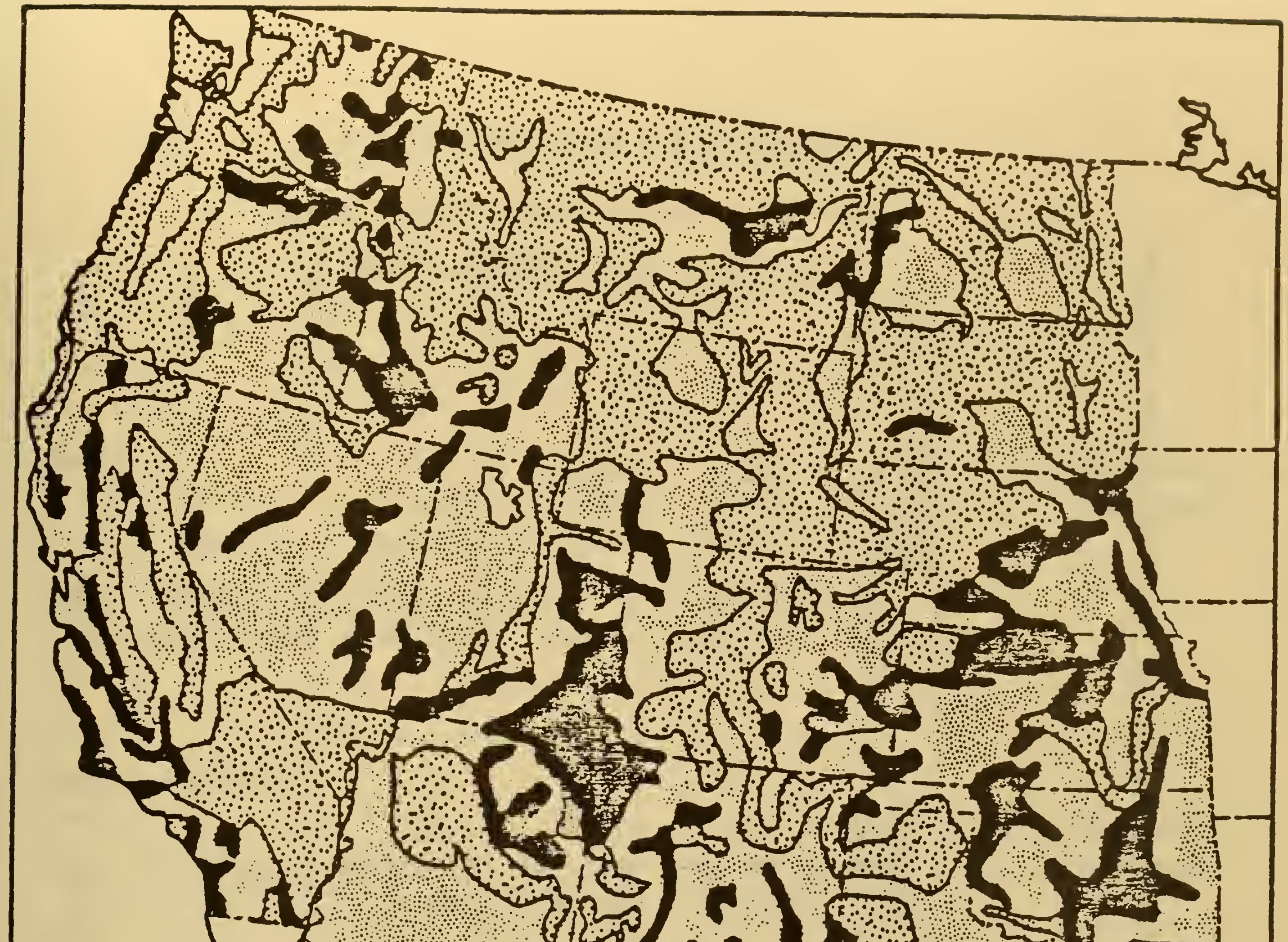


**Figure 9: Generalized soil erosion, 17 western states.**

Source: Dregne and Zartman, 1980.

Figure 10:

Distribution of Excess Sheet and Rill Erosion, by Crop Production Region and State

| Crop production region & state | Cropland | Acreage eroding at 5 tons/acre/year or more | |
|---|---|---|---|
| | (1,000 acres) | (1,000 acres) | (Percent) |
| Mountain: | | | |
| Montana | 15,355 | 564 | |
| Idaho | 6,290 | 937 | |
| Wyoming | 2,970 | 108 | |
| Nevada | 1,107 | -- | |
| Utah | 1,815 | 21 | |
| Colorado | 11,093 | 1,036 | |
| Arizona | 1,312 | 3 | |
| New Mexico | 2,202 | 98 | |
| Subtotal | 42,224 | 2,847 | 6.7 |
| Pacific: | | | |
| Washington | 7,951 | 1,089 | |
| Oregon | 5,148 | 187 | |
| California | 10,073 | 258 | |
| Subtotal | 23,172 | 1,534 | 6.6 |
| Northern Plains: | | | |
| North Dakota | 26,913 | 2,096 | |
| South Dakota | 18,156 | 1,934 | |
| Nebraska | 20,699 | 4,733 | |
| Kansas | 28,806 | 5,191 | |
| Subtotal | 94,574 | 13,954 | 14.8 |
| Southern Plains: | | | |
| Oklahoma | 11,783 | 2,451 | |
| Texas | 30,439 | 5,548 | |
| Subtotal | 42,222 | 7,999 | 18.9 |
| Total | 202,192 | 26,334 | 13.0 |

Source: USDA, RCA, 1980.

Figure 11

# SHEET AND RILL EROSION IN THE 17 WESTERN STATES

## — NON-FEDERAL LANDS —

| Range | < 2 | 2-4.9 | 5-10 | >10 | Tons/Acre/Year |
|---|---|---|---|---|---|
| United States | 313,285 | 47,080 | 21,646 | 25,761 | (× 1,000 Acres) |
| 17 W. States | 309,710 | 46,974 | 21,600 | 25,652 | |
| Western States Percent of Total | 98.8% | 99.8% | 99.8% | 99.6% | |

| Pasture & Natural Pasture | < 2 | 2-4.9 | 5-10 | >10 | Tons/Acre/Year |
|---|---|---|---|---|---|
| United States | 105,110 | 14,240 | 7,208 | 6,995 | (× 1,000 Acres) |
| 17 W. States | 41,776 | 4,359 | 1,387 | 1,075 | |
| Western States Percent of Total | 39.7% | 30.6% | 19.2% | 15.3% | |

| Cropland | < 2 | 2-4.9 | 5-10 | >10 | Tons/Acre/Year |
|---|---|---|---|---|---|
| United States | 200,782 | 115,372 | 55,971 | 41,077 | (× 1,000 Acres) |
| 17 W. States | 121,732 | 53,703 | 17,683 | 8,982 | |
| Western States Percent of Total | 60.6% | 46.5% | 31.0% | 21.8% | |

Source: USDA, RCA, 1980.

### Wind Erosion

Wind erosion occurs throughout the arid West, and most of the land damage is found in the southern half of the 17 Western States. (See figure 12.) To a less extensive degree, wind erosion is a locally serious problem around barren mine waste dumps, recreational areas, and new and hastily-built communities.

The primary wind erosion-causing factor is the cultivation of sandy soils on the dry margin of the semiarid climatic zone, and the severity of wind erosion is dependent upon year-to-year fluctuations in weather. Approximately 4.6 million acres (1.8 million hectares) of cultivated land in the ten Great Plains States were damaged by wind erosion during the drought-parched winter of 1975-76 (October 1975 through March 1976) (Anon., 1976). This contrasts to the previous less severe winter in which 2.8 million acres (1.1 million hectares) were damaged by wind.

Wind erosion damages vegetation production by: removing the finer soil particles and organic matter from the soil; by "sandblasting" and burying the existing plant and seedlings; by accumulating dust and sand around the bases of shrubs; and by reducing the fertility and/or "tillability" of the soil.

Wind erosion also has serious adverse effects on air quality. Hagen and Woodruff (1975) calculated that particulates suspended in dust storms in the Great Plains during the 1950's and 1960's ranged from 37 to 551 million tons annually (33.6 to 500.9 million metric tons). Because of a cycle of increased rainfall, the average dropped from 244 million tons in the 1950's to 77 million tons (221.8 to 70 million metric tons) in the 1960's. Wind erosion produces a larger mass of particulates in the United States than all other primary sources combined (Dregne and Zartman, 1980). Atmospheric dust impairs human and animal health, ruins machinery, and is responsible for highway accidents. Sediment in streams and lakes interferes with fish reproduction and survival, reduces reservoir capacity, and makes it necessary to dredge ship channels. Realistic costs of these kinds of damage are difficult to calculate.

### Extent of the Erosion Problem and Control Practices

The 1977 National Resource Inventories (USDA, NRI, 1978) showed that erosion is the main conservation problem on most of the West's cropland. In 1977 average annual erosion exceeded six tons per acre on croplands of the Western States. Erosion rates in 1977 were more than five tons per acre in seven States and more than ten tons per acre in three States. A ten-ton per acre annual erosion rate is the equivalent of removing one inch of topsoil every 15 years.

Figure 12

# WIND EROSION ON CROPLAND AND RANGELAND IN THE GREAT PLAINS STATES, 1977

| State | Cropland | | | | Rangeland | | | |
|---|---|---|---|---|---|---|---|---|
| | Erosion, Tons/Acre/Year | | | | Erosion, Tons/Acre/Year | | | |
| | <2 | 2-4.9 | 5-10 | >10 | <2 | 2-4.9 | 5-10 | >10 |
| | | | | (1,000 Acres) | | | | |
| Colorado | 1,195 | 1,777 | 1,308 | 3,151 | 10 | 67 | 63 | 434 |
| Kansas | 7,381 | 3,941 | 2,861 | 2,182 | 168 | 113 | 86 | 306 |
| Montana | 3,722 | 3,767 | 1,869 | 1,546 | 40 | — | — | — |
| Nebraska | 2,923 | 1,625 | 733 | 645 | 952 | 237 | 30 | 110 |
| New Mexico | 246 | 344 | 439 | 787 | 9,837 | 4,823 | 3,318 | 6,628 |
| North Dakota | 11,135 | 6,603 | 2,301 | 303 | 127 | 47 | 20 | 102 |
| Oklahoma | 2,566 | 1,377 | 1,145 | 1,024 | 7 | 16 | 15 | — |
| South Dakota | 5,016 | 6,603 | 2,120 | 695 | 19 | 8 | — | — |
| Texas | 2,092 | 1,962 | 3,521 | 11,964 | 4,874 | 2,644 | 1,979 | 5,130 |
| Wyoming | 283 | 269 | 383 | 206 | 631 | 408 | 178 | 641 |
| Total | 36,557 | 26,268 | 16,680 | 22,403 | 16,565 | 8,262 | 5,679 | 13,361 |

Source: USDA, RCA, 1980.

In tons per acre, California, New Mexico, Colorado, and Texas have the most severe sheet, rill, and wind erosion problem. Of the nearly one billion tons of cropland topsoil lost each year to water and wind erosion across the Western States, only about one-fourth is balanced by the natural soil formation under normal agricultural conditions.

Erosion is affecting both the public and private lands of the West. On range lands the average annual sheet, rill, and wind erosion in the 17 Western States is 4.6 tons per acre (USDA, RCA, 1980). Serious soil erosion has affected about 100 million acres, and moderate erosion over 210 million acres (40 and 85 million hectares) (Bureau of Reclamation, 1975). Erosion may also induce landslides, channel degradation, valley trenching, and floodplain scouring.

Figure 13 shows the Erosion Condition Classification on BLM land and on State and private land.

The system used to classify the soil condition does not adequately reflect the loss of biological productivity of the land. For example, a "moderate" soil erosion determination, upon close examination, reveals conditions which significantly reduce the biological productivity of the area surveyed. The relationship between erosion and productivity has not been established for use in management plans.

Within the arid regions, the economic feasibility of controlling wind and water erosion decreases as the climate becomes drier. In the wet fringes of the semiarid zone (east of the 100th meridian), control of water erosion on cultivated land is much more likely to return a profit in five to ten years than is water or wind erosion control on the drier side of that zone. The reason is not only that land productivity is higher in the wetter areas, but also that water erosion is easier to control than wind erosion. Residue management is one of the best tools for wind erosion, but management becomes deficient if there is little residue.

While one erosion control practice has been losing popularity, another has been gaining. Shelterbelts (windbreaks), though effective if managed properly, have become less acceptable in the 1960's and 1970's than in earlier years. The main reasons are that they usually occupy land that could be cropped; the larger size of today's farm machinery; and their interference with the use of center-pivot irrigation systems (Figure 14). On the other hand, minimum tillage and no-tillage systems keep stubble on the land to effectively protect it from wind and water erosion. (See USDA recommended practices listed under Agency Programs in Section II G.)

Figure 13:

Erosion Condition Classification Totals, 1979 (acres)

Ten Western States*

| | Stable | Slight | Moderate | Critical | Severe | Total |
|---|---|---|---|---|---|---|
| BLM Land | 12,870,134 | 78,394,851 | 51,753,040 | 10,269,252 | 672,512 | 153,959,789 |
| | 8.4% | 50.9% | 33.6% | 6.7% | .4% | 100% |
| State and Private Land | 4,698,219 | 22,581,950 | 14,254,634 | 2,646,350 | | 44,181,153 |
| | 10.6¢ | 51.1% | 32.3% | 6.0% | | 100% |

Source: BLM Inventory System Division, Denver Service Area, 1980. Private communication.

Figure 14

## Summary of Statistics on Field Windbreak Removals for Five Great Plains States, 1970 and 1975

| State | Acres | | Miles | |
|---|---|---|---|---|
| | 1970 | 1975 | 1970 | 1975 |
| North Dakota----- | 101,635 | 101,573 | 21,569 | 22,546 |
| % of total----- | 35.8 | 36.6 | 56.8 | 58.3 |
| South Dakota----- | 48,513 | 47,789 | 3,808 | 3,778 |
| % of total----- | 17.1 | 17.2 | 10.0 | 9.8 |
| Nebraska--------- | 84,159 | 79,484 | 7,661 | 7,455 |
| % of total----- | 29.7 | 28.6 | 20.2 | 19.3 |
| Kansas----------- | 34,677 | 34,948 | 3,521 | 3,521 |
| % of total----- | 12.2 | 12.6 | 9.3 | 9.1 |
| Oklahoma--------- | 14,722 | 14,155 | 1,443 | 1,384 |
| % of total----- | 5.2 | 5.1 | 3.8 | 3.6 |
| Total------- | 283,706 | 277,949 | 38,002 | 38,684 |
| Change----------- | | -5,757 | | +682 |
| % change from 1970-------- | | -2.1 | | +1.8 |

Source: USDA, RCA, 1980.

Two general strategies developed by USDA that can be applied for soil and water conservation are:

(1) to change the incentives:

- Call more attention to existing rewards from conservation.
- Increase the rewards for conserving, by giving preference in other programs to those who have achieved conservation goals (the "green ticket" approach).
- Provide more cost-sharing, tax incentives, and/or other forms of recognition.
- Increase the burdens for failing to conserve, by requiring minimim conservation achievement for participation in other programs.

(2) to change the organizations:

- Fine-tune existing programs.
- Overhaul the program evaluation process at the Federal level.
- Provide for joint State-Federal development of programs.
- Focus on development of multicounty projects carefully selected and targeted by local groups.

### b. Nutrient Loss

Calculations based on soil erosion data suggest that nationally, more than 50 million tons (45 million metric tons) of plant nutrients (nitrogen, phosphorus, potassium) are lost annually from cropland soils. The cost of replacing the nitrogen, phosphorus, and one-fourth of the potassium in the entire U.S. agricultural soil was estimated to be several billion dollars about 10 years ago. While that figure refers to total U.S. loss, the magnitude of erosion in the Great Plains and the Pacific Northwest indicated that western erosion probably accounted for a nutrient loss worth at least $500 million (Dregne and Zartman, 1980).

The fundamental issue is that decreased yields are the result of the loss of soil nutrients. If productivity is to be maintained, fertilizers should be added to make up for the nutrient losses. This is an additional cost to agricultural production. The increase of commercial fertilizers consumed in the three regions of concern and in only two years is shown in figure 15. The most recent figures indicate a stabilization in amounts of fertilizers appled due primarily to the recent escalating cost of fertilizer.

While nutrients in the cropland are a valuable asset, they are washed into streams and water bodies where they can be a detriment. Nutrients contained in waters are a stimulant to the growth of algae in surface-water bodies receiving such wastes. Problems stemming from this fact have been growing rapidly in all parts of the country, and specialists in the field are anticipating that the requirements for wastewater treatment will have to be revised to include removal of excess nutrients. The two major offenders are nitrogen and phosphorus, both of which are abundant in water

Figure 15:

### Commercial Fertilizer Consumed

(tons)

| Region | 1975 | 1977 |
|---|---|---|
| Great Plains | 6,363,609 | 8,027,664 |
| Mountain | 1,653,162 | 1,875,997 |
| Pacific | 5,086,523 | 5,876,968 |

Source: USDA, Agricultural Statistics, 1978 drained from land surfaces, in rainwater itself, in waste discharges from cities and industry, in agricultural runoff, and in feedlot runoff (Geraghty, 1973).

More than half of the surface-water bodies in the country are believed to be affected to some degree by nutrient-rich wastewater (Geraghty, 1973). Groundwater can also be contaminated by fertilizer application, as in the O'Neil Irrigation Unit in Nebraska, where nitrates in the groundwater exceed drinking water standards (Kaemf, 1980). In figure 16, the relationships between land uses and nutrient concentration in streams is presented. The dramatic increase in the usage of phosphates, nitrogen, and potash during the last 30 years in Nebraska is an example of the direct relationship between irrigation and primary nutrient consumption, and is shown in figure 17.

Reuse of irrigation outflows could be a means of controlling the loss of nutrients from irrigated farming operations. Other principal practices for controlling nutrient loss are:

- General: eliminating excessive use of fertilizer.

- Leaching Control: Timing nitrogen application; crop rotation; using animal wastes for fertilizer; plowing under green legume crops; using winter cover crops; controlling fertilizer release or transformation.

- Control of Nutrients in Runoff: Incorporating surface applications of fertilizer into the soil; controlling surface applications of fertilizer; using legumes in haylands and pastures.

- Control of Nutrient Loss by Erosion: Timing fertilizer plow-down.

(EPA, Water Quality Mgt. Bulletin, March 1980.)

### c. Compaction and Crusting

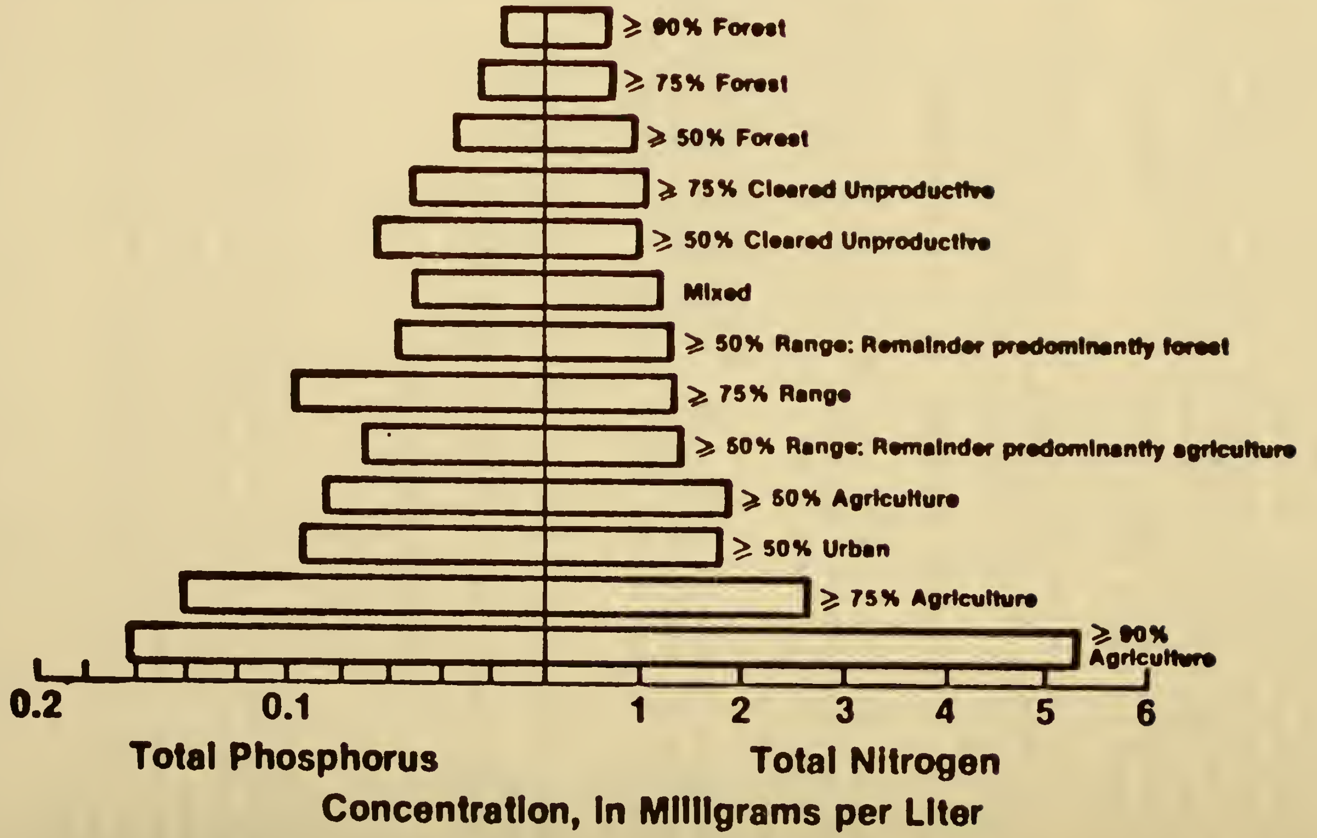
#### Compaction

Soil compaction is a serious problem in many cultivated areas. It varies with the kind of soil, the amount of organic matter, the surface texture, the kind and weight of the tillage equipment, and the moisture content of the soil when tilled. There is adequate evidence that compaction and poor soil structure lower crop yields, decrease the rate of water infiltration, and increase runoff and erosion, but the direct cause-and-effect relationships are not well understood.

The adverse effect of soil compaction is due to the reduction in the ease of root and water penetration into deeper horizons and to the reduced soil volume the roots occupy. Surface runoff is increased, plant growth is reduced, and crops become more susceptible to weather variabilities.

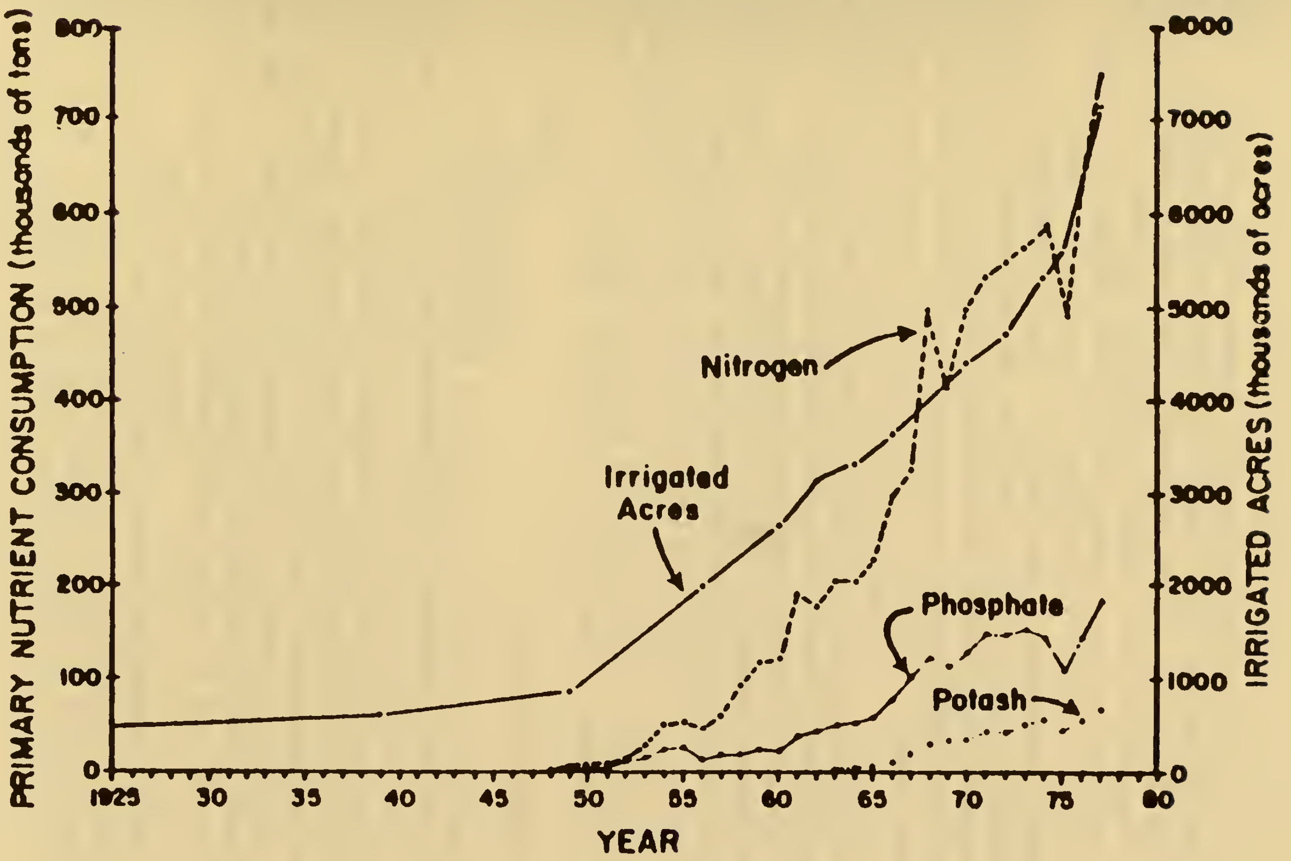
Figure 16

**Relationships between Land Use and Nutrient Concentrations in Streams**



Source: USDA/Forest Service, An Assessment of the Forest and Rangeland Situation in the U. S. (RPA), 1980.

Figure 17 - Primary Nutrient Consumption and Irrigated Acres in Nebraska



Source: USDA and Paul Fischbach, Dept. of Agricultural Economics, University of Nebraska-Lincoln, in Donald A. Wilhite, Changing Fields, University of Nebraska-Lincoln: Institute of Agriculture and Natural Resources, 1979.

Subsoil compaction on cultivated lands is common wherever tillage is done to about the same depth year after year. However, compaction of cultivated soils is reduced in modern agricultural systems by timing tillage operations for periods when soils are relatively dry, by utilizing minimum tillage practices, and by varying the depth of tillage.

Infiltration rates and the interaction of changes associated with livestock grazing are a complex phenomenon. It has been accepted by specialists that light and moderate intensities of grazing or high intensity grazing at very low frequency will not damage infiltration rates during unsaturated soil conditions.

### Crusting

Surface crusts are a major structural feature of many arid regions (Cary and Evans, 1974). Crusting increases runoff and erosion and interfers with seedling emergence. This phenomenon is most common when soils are low in organic matter, high in silt, or high in exchangeable sodium, and are without vegetation cover. These are also the conditions that make soil susceptible to accelerated wind erosion. Inappropriate cultivation practices and overgrazing tend to increase soil crusting by exposing the soil to the impact of raindrops, which effectively destroys the original structure. However, in a properly designed grazing system, hoof action can be a tool to break up crusting.

Some sprinkler systems have a similar effect on unprotected irrigated soils. As with soil compaction, data on the damage done by soil crusting are not available. It is evident, however, that the problem is a significant one when a light rain can stop seedling emergence over large parts of a field (Dregne and Zartman, 1980).

As with wind erosion control, the best way to minimize soil crusting is to provide adequate plant cover to protect the soil.

### d. Salinization of Soils

The process of salinization of soils can be traced to two sources: dryland saline seeps and salinization in irrigated areas.

Dryland saline seeps are said to be the primary soil problem in the northern Great Plains (Vander Pluym, 1978) and are increasing in size and severity in the United States and across the border in the prairie provinces of Canada. About 2 million acres (0.8 million hectares) of dryland are severely affected by saline seepage (United States and Canada) and another 7 million acres (2.7 million hectares) are affected to a lesser degree. A survey in Montana showed that dryland saline seeps increased from 53,000 acres (20,000 hectares) in 1959 to 156,000 acres (60,000 hectares) in 1975. The total impact of the salinity problem has not been completely measured, especially in affected croplands (Dregne and Zartman, 1980).

Some control measures that can be applied to this problem are: intensive cropping, growing deep-rooted perennial plants, and draining wet areas. The first two practices can be carried out by the farmer; land drainage is a practice which frequently is cost-shared by the farmer and the Federal Government (Dregne and Zartman, 1980). In some areas this practice has created severe impacts on the drainage system and on waterfowl using the wetlands habitat. Drainage of wet area is governed by Executive Order 11990 and resultant regulations.

Salinization of soils can also appear in irrigated agriculture. This type of farming requires that enough water be applied for crops to grow and for soils to flush the salts left behind by evaporation. If salts are not flushed away, the roots of plants find it increasingly difficult to extract from the soil/water system the water they need to survive and thrive. This is due to changes in the osmotic pressure of water as it becomes more and more saline. (Figures 18 and 19).

There are three common ways to alleviate existing salt problems in the soil of irrigated areas. The first method is to allow natural precipitation to leach the salts below the rooting zone. This system is used primarily in low-intensity irrigation projects where there are low amounts of soluble salt present or where the precipitaion occurs at the appropriate season. Winter rains are especially effective in removing salt from the soil. A second method is installation of tile drains to remove salty water from the profile. This is effective in areas which also have problems of waterlogging. A third method is adding excess water to leach salts from the profile, in conjunction with subsurface drainage. The salt content of the soil can usually be kept at a satisfactory low level as long as the flow of water is down or away from the rooting zone.

### 3. Water

#### a. Waterlogging

Waterlogging of soils may be a direct consequence of irrigated agriculture. It arises when the infiltration rate of the soil exceeds the permeability (hydraulic conductivity) of some horizon within the soil. In that event, water accumulates within the profile and adversely affects root growth. Waterlogging can be controlled by reducing the amount of irrigation water applied, improving water and land management practices, and by draining the soil with open or closed drainage systems.

Waterlogging risk increases with the area irrigated. For the 17 Western States, the irrigated area has increased from just over 2.5 million acres (one million hectares) in 1889 to 51 million acres (19 million hectares) in 1978. The distribution of irrigated land for these 17 States is shown in figure 20.

Figure 18: Saline Public Lands in the Upper Colorado River Basin (in acres)

| State | Non- & Slightly Saline | Moderately Saline | Highly Saline |
|---|---|---|---|
| Colorado | 5,657,070 | 713,448 | 469,482 |
| Utah | 8,765,609 | 1,605,498 | 2,284,893 |
| Wyoming | 3,952,122 | 3,473,510 | 435,368 |
| TOTAL | 18,374,801 | 5,792,456 | 3,189,740 |

| | |
|---|---|
| Total Moderately and Highly Saline | 8,982,196 |
| GRAND TOTAL | 27,356,997 |

Common Agronomic Soil Salinity Classification System

| | Electrical Conductivity at 25°C. of Saturation Extract in Micromhos/Cm | |
|---|---|---|
| Salinity Class | Upper Soil Layer | Lower Soil Layer |
| Nonsaline | < 4,000 | < 4,000 |
| Slightly Saline | < 4,000 above 8 inches | 4,000 - 16,000 below 8 inches |
| Moderately Saline | 4,000 - 16,000 above 20 inches | > 16,000 below 20 inches |
| Strongly Saline (Highly) | > 16,000 | > 16,000 |

Upper soil layer = Topsoil, layer of greatest biological activity, ranges in depth from 1 to 24 inches.

Lower soil layer = Subsoil, layer of accumulation of clay, iron and aluminum compounds, and other mineral substances, is generally two to three times the depth of the topsoil.

Source: Bureau of Land Management, The Effects of Surface Disturbance on the Salinity of Public Lands in the Upper Colorado River Basin (1977 Status Report), February 1978.

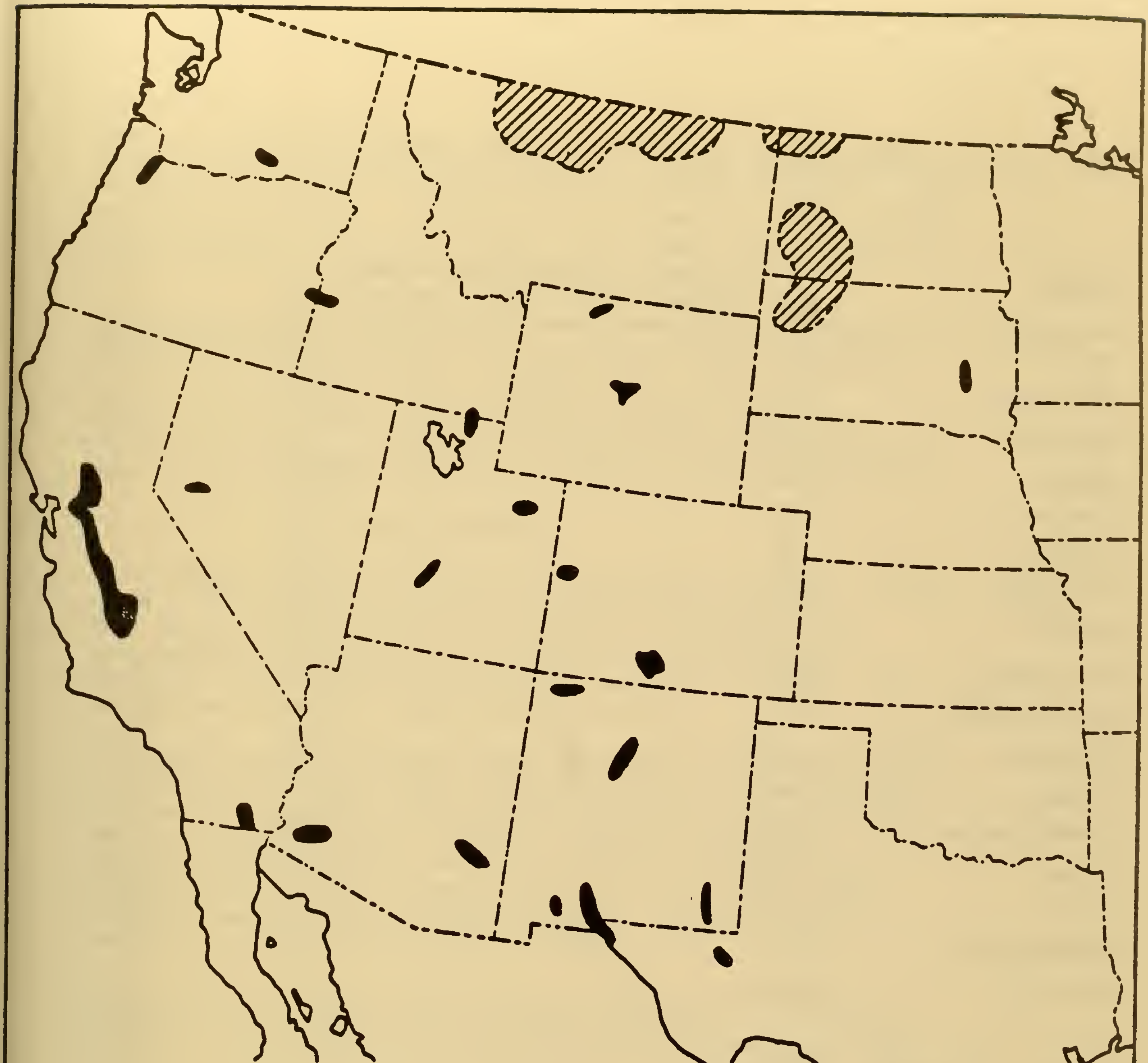


Figure 19

**SALINITY AND/OR WATERLOGGING AREAS**

Source: Dregne and Zartman, 1980.

Fig. 20: Irrigated land in the 17 western states, 1956 and 1978.

| State | Irrigated land, millions of acres | |
|---|---|---|
| | 1956 | 1978 |
| Arizona | 1.15 | 1.03 |
| California | 7.75 | 9.10 |
| Colorado | 2.38 | 3.03 |
| Idaho | 2.41 | 3.93 |
| Kansas | 0.72 | 3.42 |
| Montana | 1.89 | 3.11 |
| Nebraska | 2.01 | 7.26 |
| Nevada | 0.70 | 1.30 |
| New Mexico | 0.80 | 1.24 |
| North Dakota | 0.05 | 0.15 |
| Oklahoma | 0.29 | 0.90 |
| Oregon | 1.58 | 1.97 |
| South Dakota | 0.12 | 0.41 |
| Texas | 6.96 | 8.95 |
| Utah | 1.20 | 2.03 |
| Washington | 0.95 | 1.64 |
| Wyoming | 1.30 | 1.79 |
| 17 western states | 32.26 | 51.27 |

Source: Dregne and Zartman, 1980.

There are no good data on the amount of salinized and waterlogged irrigated land in the 17 Western States. A figure of 25 percent has long been used for the amount of land affected seriously enough to reduce crop yields. The main affected areas are in the Colorado and Rio Grande watersheds, the Great Basin region, and the Imperial and San Joaquin valleys of California.

Waterlogging is a problem that is usually profitable for the individual farmer to correct if it is due to on-farm conditions. If high water tables are due to seepage from streams, community canals, or neighboring lands, then some kind of government financing is expected to pay the cost of drainage. Drainage districts, as legal entities, are one means of obtaining community action and government financing for large-scale drainage works.

### b. Water Salinity Buildup

The amount of salt in water directly influences the utility of the water, and increased salt concentrations typically have a detrimental impact on water users and the environment. Such detriments include decreased productivity and/or increased production costs for both agricultural and industrial water users and increased municipal water treatment costs.

For agriculture, as salinity levels increase in applied irrigation water, the characteristics of soil change, and salinity levels in the root zone increase. When salinity levels in the soil increase above the threshold level of a crop tolerance, progressive impairment of crop growth and yield results. Water which has a high concentration of sodium and other ions also affects soil structure and vegetation condition of the riparian and other natural systems, impairing their quality.

For municipal uses, increases in the concentration of salinity and hardness lead to adverse health effects, lowered palatability of drinking water, added soap and detergent consumption, corrosion, scaling of metal water pipes and water heaters, accelerated fabric wear, added water softening costs, and, in extreme cases, abandonment of a supply.

The effect of water quality on industrial uses is difficult to generalize because of the varied uses required by industry. One method is to classify industrial water use by purpose, such as cooling, boiler feed, process, or general purpose. When raw water does not meet quality criteria for the specific purpose or purposes, treatment methods are required which include water softening, evaporation, demineralization, and chlorination in cooling systems for control of corrosion and slime (Kleinman and Brown, December 1980). All of these treatments add to the production cost.

## Concentration of Salts in the Streamflow

The concentration occurs partly because some of the water withdrawn for such uses as irrigation returns to the stream bearing additional dissolved material, and these salts find their way into surface and groundwaters if precautions are not taken.

Another factor influencing salinity buildup is the evaporation of water from reservoirs and irrigated fields, leaving the salts, whose concentration is increased. Evaporative losses from some reservoirs are so great that the amount of water made available for use decreases with each additional unit of storage. Any diversion of flow leaves less water to dilute high salt concentrations due to natural causes, such as salt springs. Further, consumptive losses associated with municipal and industrial water uses, evapotranspiration losses from native vegetation on noncropped land, and out-of-basin diversions of water are other causes of increasing salinity even if no more salt is added to the system (NWC, 1973). The salinity problem is increasing not only in surface waters, but in groundwaters as well. Salinity problems are in general related to poor drainage, inappropriate irrigation practices, and disturbances of saline geological formations and soils.

Erosion is a major contributor to salt loading in Western streams. Diffuse salt source areas contribute salts that are highly soluble and are concentrated in surface runoff through erosion. Over one-half of the 10.7 million tons (9.7 million metric tons) of salt estimated to flow in the Colorado River (see figure 21) is from diffuse salt source areas. Some of the critical diffuse salt areas that occur in the Western States are:

- the soft marine shales of the Pierre and Bearpaw Formations in semiarid areas of Montana, Wyoming, and Colorado;
- the Great Salt Lake and various playa lakes associated with ancient Lake Lahontan and Bonneville in the Great Basin;
- the Upper Arkansas in Colorado and the Rio Grande and Pecos drainages in New Mexico.

The Colorado River is an example of quality problems caused by dissolved solids. At present, salinity adversely affects the water supply of a population exceeding 10 million people and over 405,000 hectares (1 million acres) of irrigated land in the Lower Colorado River Basin. Salinity also affects water users in Mexico. Generally, flows in the headwaters of the Colorado River are of high quality, usually with less than 50 mg/l (milligrams/liter) which progressively increase downstream until, at Imperial Dam, the present annually-weighted condition (1976) is 823 mg/l. Projections of future salinity suggest values of about 1200 mg/l at

Figure 21: Summary of Estimated Total Runoff, Sediment, and Salt Produced from Public Lands in the Three Upper Colorado River Basin States of Colorado, Utah, and Wyoming

| YIELDS BY STATE | Salinity Class | | | |
|---|---|---|---|---|
| | Highly Saline | Moderately Saline | Non- and Slightly Saline | TOTAL |
| COLORADO | | | | |
| Runoff (ac-ft/yr) | 7,600 | 17,900 | 287,000 | 312,500 |
| Sediment (tons/yr) | 897,000 | 986,000 | 8,099,000 | 9,982,000 |
| Salt (tons/yr) | 34,400 | 19,400 | 113,000 | 166,800 |
| UTAH | | | | |
| Runoff | 36,900 | 40,000 | 445,000 | 521,900 |
| Sediment | 4,363,000 | 2,210,000 | 12,550,000 | 19,123,000 |
| Salt | 167,000 | 43,600 | 176,000 | 386,600 |
| WYOMING | | | | |
| Runoff | 7,000 | 21,300 | 201,000 | 229,300 |
| Sediment | 831,000 | 2,449,000 | 5,658,000 | 8,938,000 |
| Salt | 31,900 | 33,300 | 79,300 | 144,500 |
| TOTAL OF 3 STATES | | | | |
| Runoff | 51,500 | 79,200 | 933,000 | 1,063,700 |
| Sediment | 6,091,000 | 5,645,000 | 26,307,000 | 38,043,000 |
| Salt | 233,300 | 96,300 | 368,300 | 697,900 |

Source: Bureau of Land Management, The Effects of Surface Disturbance on the Salinity of Public Lands in the Upper Colorado River Basin (1977 Status Report), February 1978.

Imperial Dam by the year 2000. Should such salinity increases be realized, substantial environmental and economic impacts would be incurred by both agricultural and municipal users in the Lower Basin (Kleinman and Brown, Dec. 1980). However, a program is currently underway for the Colorado River to meet the salinity standards and international agreements.

Economic losses due to salinity build up are not inconsequential. Salinity build-up has reduced fisheries production, the productivity of the land base, and the palatability of water supplies for domestic use. It has also caused significant reductions in United States and Mexican agricultural production. It has been estimated that the damages to the Lower Colorado River Basin were about $447,670 in 1980 (Kleinman and Brown, Dec. 1980) (Figure 22). In the San Joaquin Valley more than $30 million are lost yearly as a result of highly saline water tables. If irrigation proceeds there in the same fashion as today, in 20 years around 750,000 acres (about 0.3 million hectares) will be affected, with an annual loss of $300 million (Grew, 1979).

It has been estimated that salinity buildup due to irrigation was costing $16 million/year in 1970 in direct damages (EPA, 1974) in the Lower Colorado Basin. If we consider that today there are approximately 34 million acres (13.7 million hectares) of irrigated cropland in the 17 Western States, the magnitude of the potential problem, where proper safeguards are not used, is worth consideration.

Fertilizer and pesticide use in irrigated and dry farming has expanded rapidly in the 17 Western States during the last 30 years. This in turn has added to the contamination of surface and groundwater resources. Section 208 of the Clean Water Act provides for State and area wide planning to identify and control nonpoint sources of water pollution, including pollution from agriculture, silviculture, mining, construction, saltwater intrusion, residual waste disposal, and disposal of pollutants to protect groundwater. Runoff is a major source of nonpoint source pollution. The initial three-year planning cycle has been completed. Currently, emphasis is being placed on continuing and State or locally-funded implementation of the plans. Site-specific planning efforts are being Federally funded with particular emphasis on urban runoff, agriculture, and groundwater.

Data on the cost of complying with Section 208 will be available when the States start implementing plans to abate nonpoint pollution. From these data the cost of controlling salinity and sedimentation could be extracted and used to calculate the cost-benefit ratios for diverse water management and conservation schemes. One example is the possible down-sizing, with ensuing substantial earnings, of the 96 mgd Yuma Desalting Plant, if irrigation efficiency of the Wellton-Mohawk District can be

Figure 22:

Salinity Damages in the Lower Colorado River Basin

| | 1976 Dollars Estimated Average $/mg/l | 1980 Estimated $/mg/l |
|---|---|---|
| Agricultural and Industrial Damages | $102,500 | $133,780 |
| Municipal (Household) Damages: | | |
| Metropolitan Water District | $187,000 | |
| Central Arizona Project Service Area | 26,300 | |
| Lower Main Stem Service Area | 27,200 | |
| | $240,500 | 313,890 |
| Average agricultural, municipal and industrial damages estimated from salinity | | $447,670 |

(USDI, WPRS, Kleinman and Brown, December 1980) improved and the drainage flow reduced.

A method to control nonpoint pollution of streamflow by salts and/or pesticides is to control runoff. Principal practices for controlling runoff are: no-till planting, conservation tillage, sod-based rotation, winter cover crop, timing of field operation, plow-plant systems, contouring, contour strip cropping, terraces, grassed outlets, contour listing, change in land use, construction of ponds.

### c. Sedimentation

Sedimentation, the product of erosion, may cause damage along streams, rivers, lakes, and wherever sediment is deposited. Sediment can result in overwash, swamping, and increased flooding. It accumulates in reservoirs, increases treatment costs of municipal and industrial supplies, makes navigable streams impassible without dredging, clogs irrigation and drainage improvements, smothers growing plants and spoils harvestable crops, increases maintenance costs of utility and transportation facilities, decreases the recreational value of water, and adversely affects the fishery resource.

This erosion problem occurs on both irrigated and nonirrigated lands. Existing erosion control technology has not been universally accepted and used, primarily because of direct or indirect economic considerations.

As cited earlier, over four billion tons (3.6 billion metric tons) of soil are picked up each year by the Nation's streams, and 25% of this total tonnage is discharged into the oceans. The other 75% is moved around within drainage basins. In the Western States one-fifth of the sediment produced by erosion ends up in the ocean. The remainder settles, as has been described, in reservoirs, rivers, and lakes, shortening their useful life. In various places it is spread by flooding over the bottomlands of watersheds and interior basins. Additionally, sediment from agricultural areas usually carries with it fertilizer, pesticides, and other soluble material which enter the receiving waters. Sediment is carried by runoff naturally, but the load increases with agriculture, grazing, timber cutting, mining, construction, dredge and fill operations, and streambank alteration especially during floods. Figure 23 shows the sources of sediment yield and figure 24 shows annual sediment yield by region.

The dollar value of damages caused by increased sediment load has not been determined, but it has been estimated at over $500 million per year. The dredging of sediments from U.S. rivers and harbors costs the nation about $250 million annually. Of the total, it seems reasonable to believe that at least half is spent in the West. The loss of reservoir capacity is conservatively estimated

Figure 23

## THE PERCENTAGES OF SEDIMENT YIELD FROM DIFFERENT SOURCES

| Sediment Source | Contribution (Percent) |
|---|---|
| Streambank | 26 |
| Cropland | 40 |
| Pasture and Rangeland | 12 |
| Forest Land | 7 |
| Roadside | 3 |
| Urban | 4 |
| Mining | 1 |
| Other | 7 |
| Total | 100 |

Source: SCS Rural Clean Water Program, Environmental Impact Statement (USDA, 1977)

Figure 24 Annual Sediment Yield by Region

| Region | Drainage Area (Sq. Miles) | Acre-feet/ Sq. Mile |
|---|---|---|
| Columbia-North Pacific | 273,784 | 0.15 |
| California | 165,177 | 0.38 |
| Missouri | 221,998 | 0.27 |
| Great Basin | 139,372 | 0.12 (minimum) |
| Upper Colorado | 113,341 | 0.45 |
| Lower Colorado | 136,333 | 0.45 |
| Rio Grande | 82,277 | 0.55 (maximum) |
| Arkansas-White-Red | 46,204 | 0.29 |
| Texas Gulf | 5,913 | 0.35 |
| Westwide Total | 1,184,399 | 0.29 |

Source: USDI/Bureau of Reclamation, Critical Water Problems Facing the Eleven Western States, April 1975. Developed from SCS/USDA data, August 1974.

to cost the country more than $50 million annually, and most of this occurs in the West (EPA, March 1980).

## E. Dynamics of Desertification

Desertification is not a mere word or invention describing nonexistent land and ecosystem deterioration. Rather, desertification is a concept, new to some, of collectively viewing the physical, ecological, and social changes which may exist in a particular region at a given time. Such a holistic view is appropriate because the various processes of change are in many instances synergistic-the total transformation is greater than the sum of the impact of each individual process, resulting in a larger reality (desertification) from the simultaneous presence of various factors. The same "total system" concept applies where rehabilitation procedures may control degradation and even enhance the quality of the resource base.

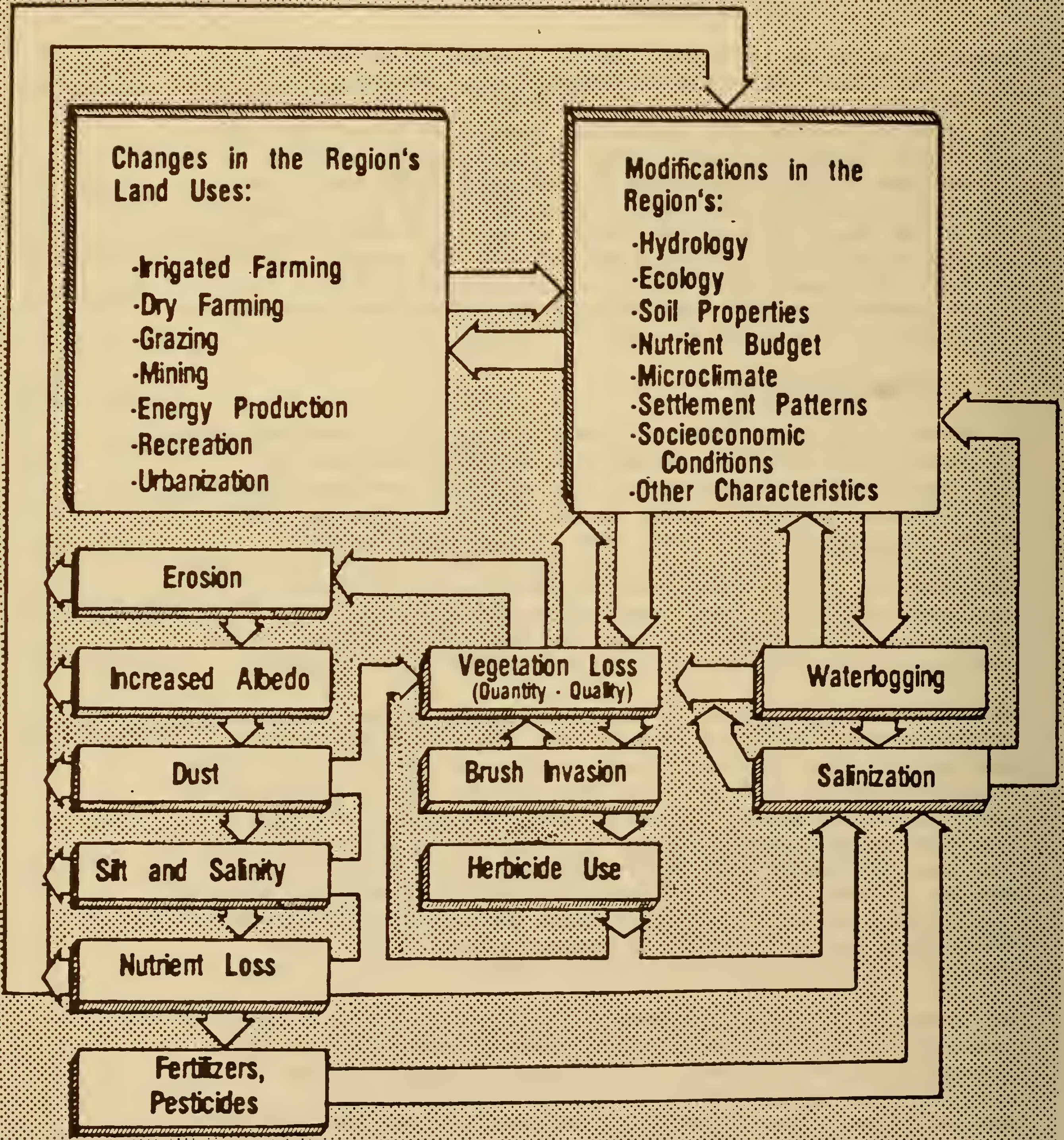
### 1. Feedback Mechanisms

As shown in figure 25, many processes are operating simultaneously and feeding back into the system as desertification sets in. Unless mitigation efforts are applied with full understanding of the processes and their interactions, the risk of making a bad situation worse is high. Also, when contemplating economic development of the resources of the dry domain (Figure 26), a good understanding of the type of environment, ecosystem traits, attempted development, and existing resources will help in projecting the modifications that the regional conditions will undergo so that unexpected or unwanted damage may be avoided.

The processes depicted should be viewed in the larger context of climatic change, not only seasonal and annual variations in precipitation but long-term cycles of drought and torrential rains. These are natural variations to which the plants and animals of an arid land ecosystem have become adapted over eons of evolution. (See Appendices E and F.) However, the productivity of the ecosystem is dependent on the availability of at least certain amounts of fresh water. When this limit is surpassed, the plants begin disappearing instead of becoming dormant, and the animals start dying instead of becoming dormant or migrating. This triggers reactions from the system to adapt to the new conditions.

One example of feedback is exemplified by the possibility that the desertification process may create climatic changes that in turn may aggravate the problem. Reid Bryson has suggested that windblown dust reduces surface heating, convection, and precipitation. Other climatologists have discussed the possibility of local, regional, or even global changes in climate induced by increased surface and atmospheric reflectivity. To greatly simplify, the energy required to drive the hydrologic cycle is less available at critical altitudes in the atmosphere and consequently,

Figure 25



Source: Sabadell, for DAUS, 1981.

Figure 26:

# ECONOMIC DEVELOPMENT OF RESOURCES IN THE DRY DOMAIN

| ECONOMIC DEVELOPMENT TYPE | NATURAL RESOURCES | | | | | | | | ENVIRONMENT TYPE | ECOSYSTEM TYPE | TRAITS OF ECOSYSTEM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | MINERALS | | PLANTS | | ANIMALS | | WATER | | | | |
| | Magnitude of Resource | Magnitude of Activity | Magnitude of Resource | Magnitude of Activity | Magnitude of Resource | Magnitude of Activity | Magnitude of Resource | Magnitude of Activity | | | |
| Undeveloped to Underdeveloped<br>--None to Low Human Activity | Low<br>to<br>High | None<br>to<br>Low | Low<br>to<br>Medium<br>(Native) | None<br>to<br>Low | Low<br>to<br>Medium<br>(Wildlife) | None<br>to<br>Medium | Low | None<br>to<br>Low | Protective | Mature | --Protection<br>--Stability<br>--Quality |
| Renewable Resources Development<br>--Agricultural Activities | Low<br>to<br>High | None<br>to<br>Low | Medium to High (Crops)<br>--<br>Low to None (Native) | Medium<br>to<br>High | Medium to High (Livestock)<br>--<br>Low (Wildlife) | Medium<br>to<br>High | High | High<br>Impoundment, Diversion of Surface Waters<br>Draft of Ground Waters | Productive | Young | --Production<br>--Growth<br>--Quantity |
| Non-Renewable Resources Development<br>--Mining, Processing Activities | High | High | None<br>to<br>Low | None<br>to<br>Low | None<br>to<br>Low | None<br>to<br>Low | High | High | Industrial<br>(Urban) | Non-Vital to Young<br>(Reclamation) | --Non-Vital |

Source: Sabadell, for DAUS, 1981

precipitation no longer offsets evaporation. These theories are still largely untested but add an ominous global overtone to the desertification question.

Energy utilization also plays a role in climate change and may therefore influence the spread and severity of desertification. In brief, as carbon dioxide from the burning of fossil fuels and, to a lesser extent, from the removal, decomposition, and burning of plant materials enters the atmosphere, it traps solar energy that otherwise would be lost to space. In a sense, this so-called "greenhouse effect" offsets the energy loss from increased reflectivity, but the possible consequences include shifts in preciptation patterns and changes in annual temperature regimes.

Another example of feedback is related to irrigation. Many arid lands are irrigated in an effort to compensate for the lack of precipitation. When it is well-designed, properly drained, and carefully maintained, an irrigation system can create extremely productive agricultural activity. However, there are serious consequences that result when irrigation plans go awry, as has been described in Section II.D. For most plant species salinization and waterlogging are detrimental, and agricultural productivity declines. This in turn modifies the region's soil conditions, hydrology, and nutrient budget, resulting in further modification of the system and finally of land uses.

The main point of this brief discussion is that any change in an arid land ecosystem has many consequences and ramifications, good or bad. If the change is considered adverse to human interests, as in those situations where productivity declines, there is a natural desire to remedy the situation but, if not done with care and understanding, there may be undesirable side effects caused by the remedies as well. This lends strength to the argument that it is better to prevent desertification than to try to effect a cure (Hinckley, 1980).

Surface water diversions may also have positive impacts. For example, desert scrub in the northeast corner of California's Imperial Valley has increased in vigor and productivity due to leakage of the Highline and Coachella Canals with the appearance of wetlands and small lakes and an increased abundance and diversity of wildlife in the local area (Coulombe, 1981). For wildlife, urbanization in arid or semiarid settings has mixed blessings. Species that depend entirely on the ground for shelter and travel (small rodents, reptiles) can be reduced substantially by urban expansion. However, many species of birds will be enhanced by the appearance of trees, shrubs, and the increased availability of insects in suburban areas. Through the urban planning process, impacts on wildlife can be reduced or mitigated (Leedy, 1978). Perhaps more important to wildlife are the secondary effects of urbanization-recreational activities that disperse into the areas around the cities and towns of the dry domain.

Introduction of exotic plants to the dry domain can have significant impacts to animals through habitat alteration. The irrigation of arid areas and the extensive corridors created by roads, pipelines, and canals have brought new plants and associated animals into the region (Frenkel, 1970).

## 2. Competition for the Use of the Resource Base

Competition for natural resources between uses and users is one added dimension to the dynamics of desertification and rehabilitation. Competition and conflicts may result when more than one maximum use, or the overuse of a resource, takes place in an area. Some aspects of multiple-use competition are the physical availability of resources and the local conditions that may influence the onset and outcome of competition. Two extremes in the usage of the natural resources of an area are (1) the ban on use, resulting in total preservation and (2) the total use of resources, resulting in depletion. In between these extremes a whole gradient of development/use/conservation mixtures of measures can be found. Depending on the value of the resource, the benefits accrued from its use, the extent of the damage (if any), the cost of rehabilitating the site, and other economic considerations, recovery may be left to the natural processes or could be speeded up through artificial repair. More importantly, these considerations may influence the selection of types and combinations of uses, number of users, and conservation measures.

Among the special characteristics of arid/semiarid lands, the limited availability of water will be discussed as an example of competition for the resource base.

Availability of water and competition: The competition for water in the arid and semiarid Western States has always been strong but is now increasing rapidly as human and animal populations, mining and industrial, agricultural, military, and recreational uses grow. As the water supplies of the Western United States are strained due to increased consumption and pollution, it is probable that less will be allocated to agriculture, and more will go for domestic and industrial use. New irrigation systems may not significantly contribute to arid land settlement for long, and the changes in land use that may follow could negatively affect the quality of the land (figure 27).

In the United States, 10 percent of the developed cropland (42 million acres) is irrigated. During 1975, 50 bgd (billion gallons per day) of groundwater were used for this purpose, representing roughly 40% of the total fresh water used for irrigation in the country. Taking into account that agricultural exports are in the range of $20 to $25 billion per year, with particular interest in specialty crops, it is evident that any detrimental change in the supply of the water and the conditions of the soil needed to maintain such activities could have serious consequences. On the other hand, in the United States today 7.5 bgd of water or 2.5% of all withdrawals are used by minerals industries (metals, nonmetals, and fuels). Water withdrawals for fuel mining and processing constitute about 36% of the total withdrawn by the mineral industry, but the consumptive use is 62% of the total mineral water consumption. Coal and oil shale mining and processing are and will be

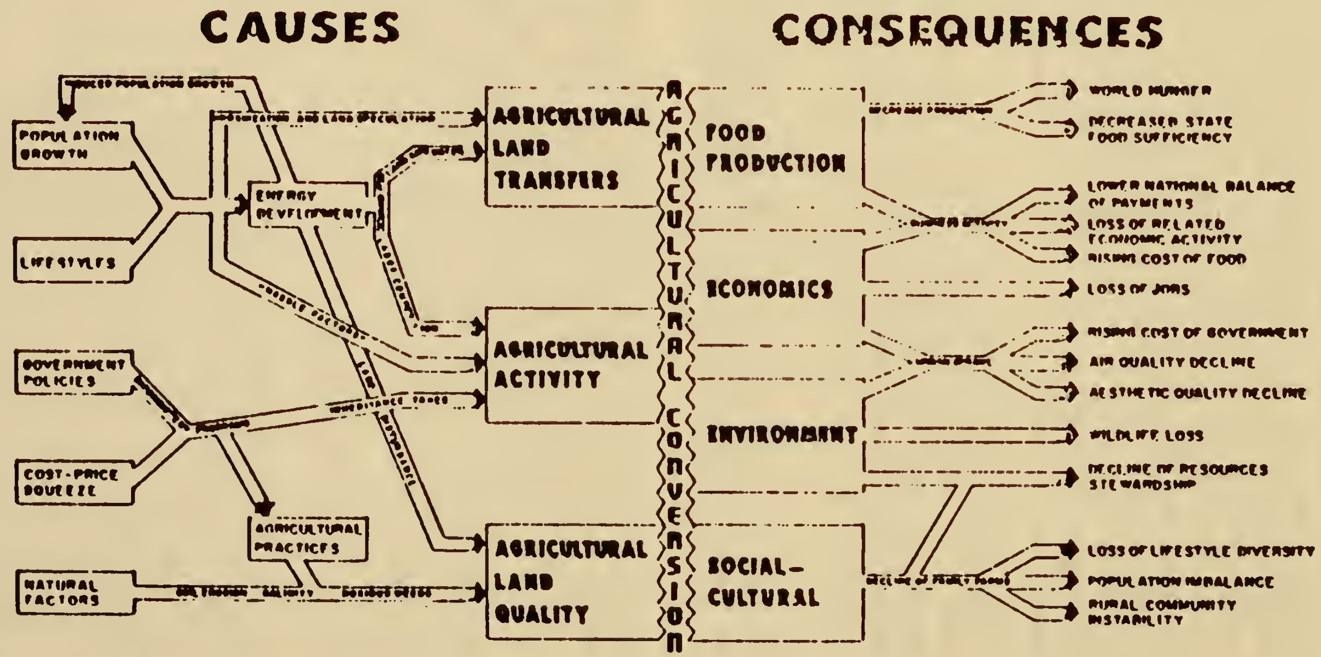


Figure 27:

**DYNAMICS OF AGRICULTURAL LAND CONVERSION**

Source: "Agricultural Conversion in Colorado," At the Crossroads, Colorado Department of Agriculture, 1980.

mainly located in arid-semiarid regions (a very important one being the Upper Colorado region) creating heavy competition between this and other interests for the allocation of water resources.

Water mining is increasing at an accelerated rate, largely due to agricultural and settlement uses. Overdrafts in the Texas region alone amounted to 78 percent of the withdrawals, 50 percent in the Lower Colorado region, and 30 percent in the Rio Grande region. In central Arizona, groundwater levels are declining from 7 to 10 feet per year. The future facing these regions is indeed uncertain, given the high probability of rapid groundwater depletion, even if the rate of water mining is maintained at the present levels. This can certainly affect the quality of the land and future land uses.

Aside from the expected population growth in the United States, an internal migration from the "Snow Belt" to the "Sun Belt" is occurring at an increasing rate, with a popular preference for the dry, warm climate of the Central and Southwestern States. One impact of this trend is that a projection for the year 2000 is of an increment in water withdrawals and in the water-consumptive use of up to 50 percent of the 1975 values for the Colorado, California, Rio Grande, Great Basin, and Texas Gulf regions. Today the total freshwater withdrawals in these regions are between 80 and 90 bgd, representing 26 percent of the total withdrawals in the Nation, 60 percent of which comes from surface water.

The projected more-intensive use of the available surface and groundwater supplies present quality problems that will become critical, requiring growing capital outlays and improved technology to solve. It is estimated that by the year 2000, there will be a deficiency in water supply for California's urban and agricultural demands totaling over two million acre-feet per year (Gertsch, 1977). All these figures show in some measure the intense interaction between the water resources of arid-semiarid regions, other natural resources, and human activity; the far-reaching consequences of changes in the existing water supply-demand system; and the probability of desertification.

Instream flow uses can also compete between themselves, and inadequate instream flow may adversely affect recreational activities, hydropower generation, navigation, waste assimilation, and aquatic life. Such low flows can be caused by excessive depletion, diversion, and operation of reservoir storage for offstream project purposes such as irrigation, thermal power generation, export to adjacent basins, municipal and industrial water supply, peaking hydropower, and flood management. These uses may affect the hydrological cycle in the area and in turn its biological carrying capacity.

### 3. Social and Economic Factors

The land uses depicted in Figure 27 implicitly present the social and economic factors influencing desertification dynamics.

a. Social Factors: In the expanding "urban oases" of the Western States, especially in the Sunbelt, the socio-cultural transformations that may result pose some important propositions such as:

- The changing social environment, resulting from rapid urbanization, sprawl, increasing densities, and industrialization may affect the vulnerability of larger population segments to desertification;
- Responses to desertification are becoming quite complex as more interdependent systems are affected;
- There is a need for more aggressive strategies requiring incentives for comprehensive natural resource development as part of long-range policies; and
- There must be a broader mobilization of institutions and people in order to accommodate adaptive policies for resource scarcities,climatic vagaries, and future environmental uncertainties.

Some of the questions that should be answered so as to cope with the special problems posed by this ongoing growth relate to the following concerns:

- The description of the stresses that are and will be taking place in the United States drylands;
- The description of the changing social arena of the West, with its variety of regions, cultural practices, and historical influences;
- The implications of changing settlement pattern; and
- The changing socio-economic--thus political--circumstances of the growing population, especially the migrants coming from more humid cultures.

Ecosystems that are impacted or stressed by increasing populations and diversified activities result in a changed or "new" environment, and a new equilibrium of ecological and social conditions results. In these evolving ecosystems, droughts and desertification are not strictly physical phenomena, but parts of an interplay between natural variations in available precipitation and some human use systems which are sensitive to them.

The central question, then, is: What is the carrying capacity, and what are the growth limits in a functioning ecosystem where supply and demand are changing?

## NATURAL RESOURCES PROBLEMS

| Supply | Demand |
|---|---|
| 1. Resource limitation | 1. Population growth |
| 2. Technological limitations | 2. Economic growth in general |
| 3. Economic and political limitations | 3. Waste |
| 4. Socio-cultural limitations | 4. High natural resource consumptive lifestyle |

These changing conditions can be seen both as threats and as opportunities for developing resource policies which recognize the needs of the country in the balancing of three important dimensions:

(a) *efficiency*, or the growth of material development so that a solid basis of economic sufficiency may be maintained;

(b) *equity*, or fair access of resources and consumption to different segments of the population; and

(c) *effectiveness*, or the overall significance of any policy vis-a-vis the pursuit of certain larger social goals.

In the balancing of supply and demand, or between development and preservation, a systematic accounting of the alternatives to be pursued and their far-reaching consequences must consider the following questions:

(1) What kinds of new ecological and social equilibria will result from any given resource development program?

(2) What are the long-term commitments in terms of environments used and resources consumed?

(3) What is the local, regional, and national significance of those commitments in terms of values and goals of various interests at each level?

(4) What are the long-term consequences of proposed plans for the use of resources? (Vlachos, 1980)

It has been suggested that to address the issues a separation should be made between "crisis management," which is a response to short-range challenges and immediate events, and "risk management," that indicates a much more flexible and long-range policy of accommodation to a changing and uncertain environment. The range of recent developments points out that the changing environment in the Western United States is a young ecosystem, responding to new sources of stress and strain. Further, competing and conflicting interests, shifts in populations, new social activities, hard decisions in allocating scarce resources, respect for native rights, and equitable cost distribution all require much more complex social policies and planning.

Comprehensive resource management guaranteeing development, survival, and fulfillment is an additional call for avoiding loss or deterioration of highly-valued natural resources and enviroment by considering the wishes of both earlier settlers and newer arrivals, as well as the interests of the region and of the Nation as a whole.

b. Economic dynamics: Frequently human activities can indirectly contribute to desertification. Examples of such factors are: unexpected side effects of administrative or fiscal State, regional, or national policy, rising local expectations and local economic demand, or changes in market conditions in regional centers. Areas vulnerable to desertification are generally (though not always) relatively sparsely populated, and their economies are exposed to the effects of dynamic social and economic events of areas with denser populations, of investment centers, and of political capitals. Local changes caused by pressures of growing population and needs, whether direct or indirect, may result in changes in land-use patterns, in the effective use of resources, and in changes of the economic base and distribution of wealth.

The process of economic marginalization can be utilized as an indicator of lowering quality in the resource base. There is a tendency for investments in arid areas to be self-reinforcing factors of lower income and lower population density, creating the predisposing conditions for lower levels of investment. A trend toward more development makes the peoples of the vulnerable areas more dependent on investment from outside.

In the United States, the well-developed census system permits monitoring the income of farmers as an economic group. Since it measures the reality of resources available to meet felt needs and financial obligations, a fluctuation in cash income indicates the ability of farmers to hold on to their farms and may suggest the degree of risk and damage to the environment they are willing to accept in order to do so.

The difficulty of evaluating the economic factors that affect the desertification processes is that the costs to be paid when desertification damages occur; the investments to be made to prevent, arrest, and ameliorate desertification; and the benefits resulting from these measures cannot be readily handled by present analytical methods. (Duncan, 1979)

Of the many questions to be asked with regard to the real price of desertification, these are but a sample:

-In the United States drylands, do all the true inputs balance the outputs? Would taking the financial bias out of the system make a difference?

-How much does it cost the region and the Nation to use up, in the short term, certain natural resources of the area--in effect reducing the long-term yield?

- What is the impact of the changes in the size of agricultural holdings brought about by desertification on the local, regional, and national economies?

- What is the value of the "pristine environment" and of unique sites?

- What is the economic significance of converting, through excessive use, a renewable resource to a nonrenewable condition, e.g., mining of groundwater?

- What are the benefits, if any, between preventive and remedial actions where environmental quality is concerned? An example would be to compare the costs of re-establishing the vegetative cover in parts of the Rio Grande basin against the water treatment costs necessary to remove sediments and salt loads so as to comply with EPA regulations?

- What are the effects of air quality on the health, social, and economic conditions of populations impaced by desertification, and how much does this cost society?

- What are the economic consequences of conservation practices for various land uses when using short-and long-term time horizons? (See figures 28 and 29.)

## F. Inventory, Monitoring, and Trend Determination

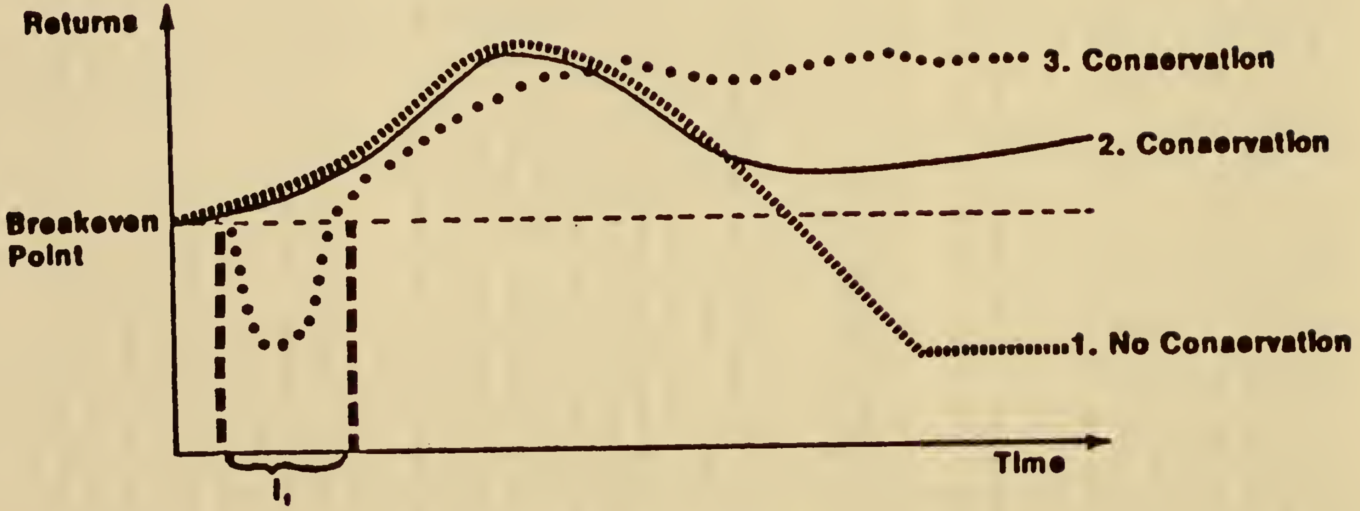
### Introduction

Processes described in Section IID contributing to changes in the quality and productivity of arid and semiarid lands can be observed, measured, and assessed. However, overall conditions currently are often described in inadequate terms. There is a recognized need for improved methods of data gathering, conversion, and analysis, and for useful reporting systems on the status of areas prone to desertification. Whether conditions are worsening or, under effective mitigating procedures, showing improvement is of primary importance to measure the effectiveness of the actions taken and of the technologies applied. Inventories are useful in supplying the necessary baseline, but sustained monitoring programs will need to be instituted to record changes and determine long-range trends.

On April 28, 1981, speaking before a House Subcommittee, Interior Secretary Watt stated that the Nation must undertake a full inventory of all its natural resources. He added that, "With all of America's greatness, we still do not know the full extent of our mineral values, our agricultural values, our agricultural potential . . ." A principal State Department spokeman for environmental affaris, Deputy Assistant Secretary Marshall, in a speech delivered March 26, 1981, argued for the "urgent need to improve the data base required to plan and assess management programs across a wide range of resource and environmental areas." In the same statement Marshall noted the world problem of losses in valuable cropland caused by such factors as "desertification, erosion, waterlogging, and soil salinization." Secretary of Agriculture Block has recently spoken of the need to address the continued loss of cropland in this country.

Figure 28

**Returns from Dryland Farming with & without Conservation Practices.**



Curve 1: No Conservation - withdrawal from production

Curve 2: Conservation with investments in fertilizers, legumes, rotation contour plowing, etc.

Curve 3: Conservation with initial investment ($I_1$) in terracing, grassed waterways, fences, gully check dams, etc., plus above mentioned conservation practices

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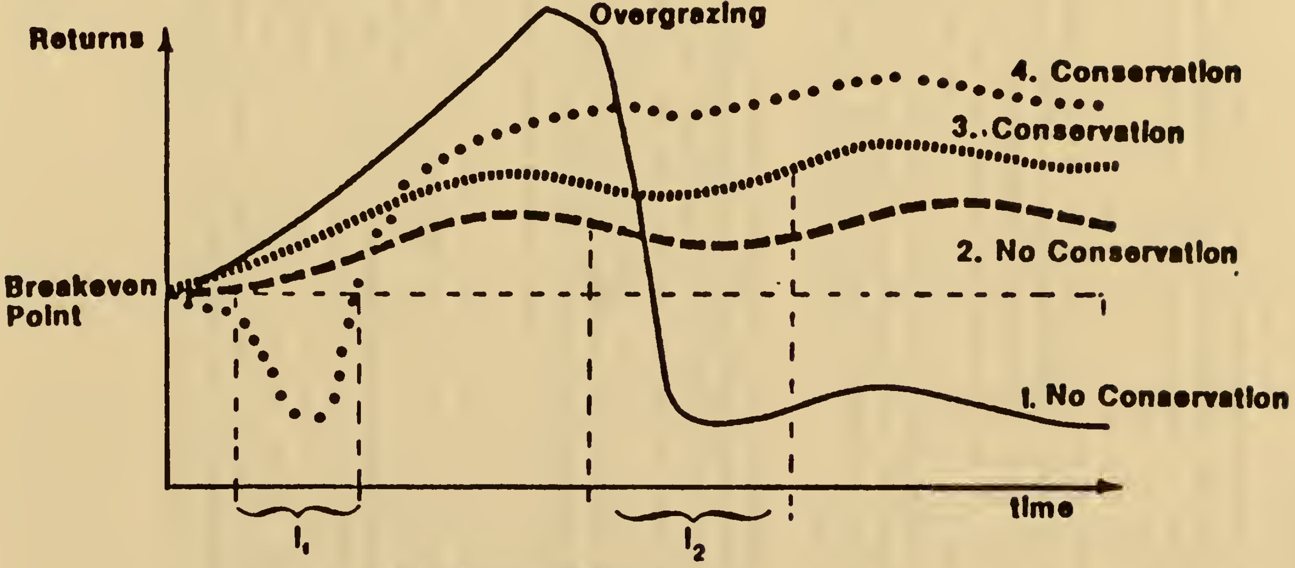
Source: Modified from A. Warren & J.K. Maizel's, "Ecological Change and Desertification," 1977.

Figure 29

## Returns from Livestock Activities with & without Range Conservation Practices (Response to Rainfall Included)



—— Curve 1: No conservation and overgrazing

▬ ▬ ▬ Curve 2: No Conservation

•••••••••• Curve 3: Conservation and no overgrazing. Low level investments ($I_2$ - rotation, culling, plowing, etc.)

● ● ● ● ● Curve 4: Conservation & no overgrazing. High level initial investment ($I_1$ - fences, wells, irrigation, terraces, rotation, culling, etc.)

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Source: Modified from A. Warren & J.K. Maizel's "Ecological Change and Desertification."

## 1. Data Base and Inventory

The area of the United States vulnerable to desertification is a discrete geographic area which can be classified according to a broad synthesis of climate and dominant physical and biological characteristics. (See Appendices D, E, and F.)

Identification of its natural boundaries assists the preparation of data bases for resource inventory. It defines the area for purposes of information storage and retrieval on identified targets so that changes and trends can be monitored and focused on specified indicators.

It is important to distinguish between inventory, the description and evaluation of basic resources and characteristics of the land, and monitoring, which provides a means of assessing the dynamics of change in the land and its resources.

The Bureau of Land Management (BLM) Rangeland Inventory Analysis (draft dated Dec. 12, 1980) for example, regards inventory as both a short-term tool for making management decisions and a long-term means for establishing a base for monitoring the effectiveness of management decisions. It also considers that inventory data should not be static but should become more accurate as monitoring data is continually added to the data base. Considerations of cost, effectiveness, and degree of intensity appropriate for different management purposes are addressed in this manual.

While Federal, State, and local agencies have conducted land inventories for specific purposes, assessment of desertification status has been impeded by the absence of agreed standards and objectives and of suitable data collection. The available methods are generally not geared to determine whether observed changes in the quality of land use are the result of human activity or are related to natural processes. Improved techniques are needed for determining long-term trends, such as climatic patterns, as well as methods for understanding the shorter-term impacts and consequences of resource utilization.

## 2. Monitoring Principles

Three compelling reasons for establishing monitoring systems applicable to identifying and measuring desertification are: greater scientific understanding; increased public awareness; and the ability to take responsible, appropriate action. A comprehensive system that would include a multidisciplinary, multijurisdictional assessment of environmental changes would have widespread applicability to resolving these and related concerns and would describe the nature and pace of these changes. A number of State governments have adopted or are instituting effective earth-based information systems which can accommodate relevant types of data. New tools for observation, notably remote sensing and rapid data management, will make possible repetitive surveillance of the vast dry and largely barren areas where it has not been cost-effective in the past to prepare adequate data bases or to periodically revisit to determine changes.

General principles governing the collection and use of data include:

- Quality assurance of the data is to be maintained through standardization and constant auditing.
- The several types of data collection - ground satellite and aerial - must produce data which will be complementary and applicable at several levels from local to regional to national.
- Local participation in the collection and analysis process will assure more useful data and greater willingness to take corrective action where indicated.
- Data must be developed and stored in ways to be quickly available in a user - oriented form.
- Monitoring and inventory procedures should be designed to facilitate incorporation of data into a larger data base for land management.
- The dissemination of monitoring data must be directed toward providing incentives for National, State, local governments and private interests to implement and maintain corrective and preventative measures.

The results of contemporary inventory and monitoring can be complemented by comparison with available historical data, and by incorporating data from other sources outside the area of concern. For further discussion see Appendix M.

## 3. Coordinating Environmental Data

Reliable and comprehensive monitoring requires coordinated data collection, processing and analytical techniques, as well as agreement among disciplines and jurisdictions on criteria and format to be used. This is essential to determine the existence and extent of desertification and the effectiveness of possible remedial or mitigating actions. A number of Federal, State, and local agencies have responsibility to provide for the multiple-use management, protection, and development of the arid and semiarid lands of the Western United States. These organizations are already engaged in various forms of data collection and monitoring and specific statutory authority governs the type and purpose of information gathering. Recent progress in standardizing monitoring systems has been evidenced through interagency agreements to facilitate improved inventory information exchange and better State and Federal coordination, as well as a start toward development of common classification schemes.

### 4. Limitations of Existing Monitoring Procedures

Environmental monitoring for large regions presently is difficult to accomplish at acceptable costs using conventional surveys. However, supplementing ground collection with remote sensing systems shows promise for future coverage of large regions efficiently and economically. Some programs have demonstrated the feasibility of interagency ancillary data, particularly early digital terrain data, with Landsat data.

Recent studies by Federal and State groups have examined domestic capabilities for environmental inventorying and monitoring. A general comment has been that quantities of specialized data are collected in a multitude of formats on specific environmental topics. Coverage tends to be spotty, with concentration of data on areas of apparent greater economic potential. However, there has been increased emphasis on presenting information in a total or holistic form.

Another major area of concern is that inadequacies in data collection have resulted in delay in Federal projects, redundancy, and poor coordination with State programs.

### 5. Indicators of Desertification

The complex processes affecting desertification, discussed in earlier sections, can be understood and measured provided that they are based on an agreed-upon multi- and interdisciplinary set of critical indicators. This need was recognized in the course of studies accompanying the United Nations conference of 1977 and afterwards in follow-up activities. Studies of indicators prepared by Clark University and the Association for the Advancement of Science agree that: (a) indicators should provide a diagnostic index of the extent and intensity of the process, (b) useful indicators should distinguish among natural and human-induced phemonmena affecting desertification, and (c) indicators should provide not only evidence of desertification having occurred, but also be the main components of a warning system.

Some principles for indicators are that: (1) they should be directly measurable; (2) the unit of geographic reference must be specified (whether one meter or transcontinental); (3) the stage of desertification should be specified, recognizing that phases of desertification range from mild effects to practically irreversible conditions; and (4) quantitative and qualitative standards must be associated wherever possible.

The importance of an agreed-upon set of indicators is based on the need to avoid overaccumulation and underanalysis of data both because of cost considerations and the adverse effects of overloading analysts and decisionmakers. It is also necessary to provide sets of indicators reflecting regional differences both in physical parameters and in social institutions. To facilitate practical monitoring programs, representative sample areas to serve as readily-observed benchmarks or "control" sites should be identified.

Three sets of linked, critical indicators were defined by the Nairobi Seminar on Desertification. They are presented here and in the accompanying tables, in simplified form under the broad headings: (1) physical; (2) biological/agricultural; and (3) social. In addition to indicator classes, figures 30, 31 and 32 also show sources of observations or data, for example, on ground or remote sensing, desired frequency of observation, and background data variables.

This list of indicators has been modified in this study for adaptation to the situation currently prevailing in the United States. Thus, physical indicators include climate, soil, land forms, and water; biological factors include flora and fauna; and social indicators address population dynamics, economic dyamics, and production or economic uses of the land. A brief discussion on the significance of principle indicators for desertification follows.

### a. Landforms

There are a variety of landforms which reflect the effect of water and wind on the surface of the earth. Features include sheet erosion, rills, and gullies. Important indicators include arroyo cuts and fills, dune formation and migration, yardang (irregular ridges formed by aeolian erosion) formation, playa growth and dessication, pediment processes, and mass wasting.

### b. Soil

The washing away or blowing away of soil is an important indicator of desertification which is regulary measured both in site and in transport. Hydrological data on suspended sediments have been recorded for parts of the Southwestern United States for many decades. Some of the quality-of-soil indicators, also listed in

Figure 30 Biological/Agricultural Indicators (Revised)

| Indicator Class | Sources of Data | Frequency of Observation | Background Data Variables |
|---|---|---|---|
| Vegetation | | | |
| Cover | production<br>% of bare ground/ground cover in dry season: aerial photos and observation, remote sensing | annually and seasonally | % of ligneous/herbaceous plants<br>% annuals/perennials |
| Above-ground biomass | chlorophyll content: remote sensing<br>production transects and quadrats: ground sample and lab analysis<br>preservation plots | monthly/seasonally<br>3-10 year intervals<br>long-term measure<br>short-term index | net assimilation<br>climate<br>soil type<br>erosion<br>below-ground biomass<br>% of ligneous/herbaceous plants |
| Key species | potential vegetation communities<br>records, manuals<br>ground observation of transects<br>utilization levels with known animal populations | list compilation: 6 mos. - 1 yr.<br>observation: seasonally | range ecological condition and trend<br>the effect of utilization by different animals |
| Yield | grams of dry weight/square meter/year or season | annually or seasonally | short-term effect of fertilizers<br>yield by species of plants in climax community and seral community desired on the site |

Figure 30 - Continued

Biological/Agricultural Indicators (Revised)

| Indicator Class | Sources of Data | Frequency of Observation | Background Data Variables |
|---|---|---|---|
| **Animal** | | | |
| Key species of wildlife: frequency and distribution | arthropods<br>small mammals and birds | annually or seasonally | relation and competition with domestic herds |
| Population of domestic animals | numbers and distribution of large and small stock based on livestock management censuses | annually or seasonally | carrying capacity of range; physical and vegetation indicators |
| Herd composition | composition of herds | annually or seasonally | physical and vegetation indicators determine diverse types of forage available. Variations in rainfall |
| Production | live weight of animals at market<br>milk, meat | annual statistical review | purchase of supplementary cereals |

Modified from Reining, Handbook, 1978.

Figure 31: Physical Indicators of Desertification

| Indicator Classes | Source of Observation | Frequency of Observation | Background Data Variables |
|---|---|---|---|
| *Landform* | Ground and remote | Annually | Soil and rock type |
| *Soil Indicators*<br>Effective soil depth (changes indicate soil removal and sedimentation) | Ground and remote | Monthly - Annually | Rainfall<br>Slope of land<br>Soil texture<br>Soil structure<br>Wind speed, etc. |
| Soil organic matter | Ground (permits estimate of organic matter by inference from color) | Monthly - Annually | -- |
| Crusts | Ground and remote | Monthly - Annually | -- |
| Dust, duststorms and sandstorms | Ground and remote | Daily | Windspeed<br>Temperature<br>Soil structure<br>Geomorphology |
| Salinization, Alkalization | Ground | Monthly - Annually | -- |
| *Climate* | Ground and remote | Daily | -- |
| *Water Indicators*<br>Water, ground depth and quality | Ground | Monthly - Annually | -- |
| Water, standing open | Ground and remote | Monthly - Annually | Area, depth and turbidity |
| Status of drainage | Ground and remote | Monthly - Annually | Water flow and sediment load |

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Modified from Reining, Handbook, 1978.

Figure 32: Social Indicators of Desertification

Social indicators described in Handbook on Desertification Indicators, modified for United States application.

Changes in land use

- Irrigation
- Dryland agriculture
- Rangeland
- Mining
- Tourism and recreation

Settlement patterns

- New and sudden expansion of settlement
- Diversification of settlement
- Settlement decline and abandonment

Human biological parameters

- Population structure and rates
- Public health indices and nutritional status

Social process parameters

- Redistribution patterns
- Income patterns

Modified from Reining, Handbook, 1978.

figure 30, are depth, organic content, crusts, and salinity. Degradation of soil may occur in progressive stages requiring different sets of indicators to monitor. For example, an increase in salts or alkalis affects vegetation, microorganisms, and ph, and decreases permeability and amount of useable water. In advanced stages, the visible manifestations are likely to be white or gray surface coloration and saline crusts.

### c. Climate

Coordination of rainfall information with other information on change such as measures of bare ground and dust storms are provided through a number of services. On a global basis, the World Weather Watch (WWW) gathers climatic data from synoptic stations which includes cloud cover, vertical temperature, humidity, snow cover, land surface temperature, precipitation, and so on. Major abnormal weather conditions are reported weekly by the National Oceanic and Atomospheric Administration (NOAA). Solar radiation, ozone, carbon dioxide, and sulphur dioxide, all contributors to climate and climate change, are also monitored and reported by NOAA. While the reports have no direct link to desertification processes, the data is designed to help land managers deal with declining productivity. The present objective of climatologists is to provide long-term "benchmark" data in order to direct climatic shifts. Trends derived from studies of archeology, paleontology, and dendrochronology (tree rings) aid in determining past climates.

### d. Water

Continuing declines in groundwater levels, the degradation of water quality, and the progressive loss of soil moisture all may serve as significant indicators of the process of desertification. These indicators are monitored by continuing groundwater level measurements in wells, chemical analyses of well water samples, and soil-moisture content measurements. Drainage and the magnitude and continuity of water flows in a drainage basin (including sediment load) are other measurements of interest. Irregular flow in streams due to desertification upstream, changes in distribution and amount of soil absorption, and changes in runoff volume, quality, and patterns may be used as indicators as well.

### e. Flora

The biological/agricultural indicators include cover, above-ground biomass, yield, and the distribution and frequency of key species. One of the most important biological indicators is the change in perennial plant cover or production. However, it must be noted that the quality of plant cover must be recorded since brush and weeds may be present in large quantities. Above-ground biomass consists of grasses, forbs, trees, succulents, and shrubs. Change in plant density and increase in the relative number of weed species, xerophytic species, and of unpalatable plant species may be indicative of a downward trend. Vigor of species, grasses for example, is important to observe. However, it must be noted that wildlife may benefit by species normally unpalatable to domestic livestock. Prediction of trends depends upon appropriate sampling, taking into account size, production, and density of desired subject vegetation and the characteristics of particular mixed stands.

Using vegetation as an indicator of desertification in arid areas has special difficulties in that the indicator species are fewer in number, often difficult for trained individuals to recognize, and even more subject to functions of extreme weather conditions and other natural events such as insect infestation. As in all indicator systems, an adequate data base must be present to establish long term management decisions.

### f. Fauna

Fauna indicators include key species of wildlife as well as domestic animal populations. Insects, birds, and some species of small animals, particulary rodents, can be identified as key indicators of desertification. Population of domestic animals encompasses numbers and types of stock. The proportion of the number of animals to units of grazing land, or range carrying capacity, is normally considered to be site-specific. The concept of carrying capacity in renewable resource management is used to indicate the level of sustained use at which the resource will not be permanently damaged or its productive capacity lowered. There is a close correlation between flora and fauna indicators, especially when applied to rangeland condition. Since a high proportion of cattle are living in arid or semiarid areas, the rangeland indicator of trend, in addition to condition of the soils, is the presence and production of plants in relation to the production by species in the climax community on the same ecological site. In this way, flora actually determines fauna. Finally, in another context, many wildlife species are characteristic of desert conditions, and trends in their population are also indicative of conditions.

The factors dealt with above, concerning physical and biological indicators, interact in a very complex way with "social" variables, that is, the wide range of human activities which impact directly and indirectly on the range of environmental attributes. Figure 32 has broken the social indicators down by change in land use, settlement pattern, human biological parameters, and social process parameters. As pointed out in The Handbook on Desertification Indicators (Reining, 1978), "any social indicators selected are more likely to be suggestive of desertification rather than positive proofs of its existence." Social indicators assume a temporal dimension, a means of indicating trends in human land-use activities.

Data on social indicators must be site-specific. Indicators from different areas may be integrated or used for spatial references.

Indicators should also be capable of measuring success in combating desertification.

### 6. Monitoring and Assessment Systems of the United States

Major United States collection systems are currently collecting detailed information on weather, hydrology, range conditions, and other environmental factors. For further discussion see Appendix M.

In a one-time study directed by the Council of Environmental Quality (March 21, 1980), an interagency task force surveyed U.S. monitoring resources. Major areas of concern included: coordination; quality assurance; cross-media analysis; budget consideration; redundancy; and land use data issues. The task force report recommends a program to design long-term ecological measurements and improve resource data reflecting relationships between human impacts and long-term natural environmental processes.

### 7. The Potential of Remote Sensing Systems

A significant recent development was the Administration's decision to support NASA and NOAA in their budget requests to proceed from the experimental Landsat phase to a fully operational satellite system with consequent assurance that timely data will be routinely available to Federal, State, and local users by the end of the decade.

The interagency national High Altitude Photographic (HAP) Data Base Program is obtaining coverage of the United States in three years with high-quality photography. HAP data are being entered into the data base at the EROS Data Center, Sioux Falls, South Dakota. Periodic updates of the base index are available through the U.S. Geological Survey's National Cartographic Information Center (NCIC). The high-altitude aircraft data base program and the global Landsat program will effectively complement one another. Another significant advance is the creation of programs to train State and local users in the application of these new data and to assure the quick availability of data at a reasonable cost.

## G. Conservation: Programs and Practices

Available procedures for the conservation of natural resources and control of desertification are based on these elements: (1) appropriate legislation at the Federal, State and local levels; (2) institutional arrangements setting up cooperative procedures for agencies with jurisdiction or expertise on environmental quality issues; and (3) the application of innovative technology for halting desertification processes utilizing incentives whenever possible and bringing about their possible prevention and abatement.

The existing legal and institutional arrangements by and large provide a framework for cooperation. However, such a framework is not always used to its fullest and best extent. For example, it is generally accepted that the main water problems of arid and semiarid lands do not exist because of technical incapacity, but because of deficiencies in the institutional arrangements and regulations.

The goals and values of closely-related institutions often are seen as clashing. The trend toward greater centralization of government, combined with a heightened concern for natural and wildlife resources, has fostered competition rather than cooperation between the States and the Federal Government. Federal advocates make the argument that theirs is the broader jurisdictional reach and that, for example, populations of animals should be subjected only to integrated and systematic management of a sort which have often not been applied at the State level. In rebuttal, the States maintain that they, after all, are on location in the field with the personnel and the initiative to deal with the problems at ground level.

A brief discussion on institutional responsibilities, existing legislation, conservation programs, and conservation practices and projects follows.

## 1. Institutional Responsibilities

In 1978 the Council on Environmental Quality prepared a compilation of all Federal agencies with jurisdiction by law or special expertise on environmental quality issues. The list is organized into four broad categories: pollution control, energy, land use, and natural resource management. Under each category, the agency as well as its component bureaus are listed with a brief description of their jurisdictions. This list was published in the Federal Register, October 19, 1979 (vol. 44, no. 204) and is included in Appendix K.

At the Federal level alone, more than 25 agencies have some function related to land and natural resources management. Similar organizations exist at the State level, and lists of such agencies are available from the States. It has been found that the priority and support given to conservation programs varies greatly from State to State, even within the same region, and even when facing the same or similar problems. Coordination of conservation efforts and of resources planning and management among and within Federal, regional, and State agencies has been far from ideal. Implementation has been inconsistent. Effective arrangements are available; examples include several river basin commissions. Education and incentives could encourage cooperation.

It has also been found that no cohesive land and natural resources policy exists today. In part this fragmentation is due to the historical origins of actions and policies, to the diverse goals of the various Federal agencies, and to their sometimes conflicting missions. These missions fall into four main categories:

management of lands; pollution control; resource development; andresource protection/preservation (Aspen System Corp., 1979). Arguments for and against regional planning have been expressed, and although several attempts have been made through the years, there is as yet no satisfactory resolution.

## 2. Existing Legislation

A summary of main existing land and natural resources laws can be found in Appendix L. In some instances these laws encouraged (among other unsound practices) what proved to be overexpansion of western agriculture and cultivation of marginal lands and incentives for the overuse of soil and water resources. It appears however, that a change in this situation is imminent. The recently passed PL 9798, the Agriculture and Food Act of 1981, contains a section which encourages resource conservation measures such as conservation tillage. If this type of encouragement proves successful, possibly stronger incentives for conservation measures will follow.

In general, land and natural resources-related legislation responds to some environmental crisis or to a manifest national need and is generally remedial, dealing with improvement of current unacceptable conditions. Preventive measures are less often legislated. Enactments influencing land and natural resources policy are often fragmented and single-problem focused. Only recently has the multiple-use concept been legislatively recognized, with the intent of striking a balance between conflicting or competing land-use interests. This is proving to be a difficult task. An analysis of the interplay among existing developmental, regulatory, and protective legislation is needed, together with an assessment of their effectiveness singly, when compared with one another, and when and if integrated.

## 3. Federal Conservation Programs

Listed below are some main conservation programs identified as beneficial to land users in the 17 Western States, presented by agency:

### a. U. S. Department of Agriculture

#### (1) USDA Action Programs for Soil and Water Conservation (USDA, 1979)

Agricultural Stabilization and Conservation Service (ASCS)

- Agricultural Conservation Program (ACP)
- Water Bank Program
- Emergency Conservation Measures

Farmers Home Administrative (FmHA)

- Association Loans for Irrigation and Drainage and Other Soil and Water Conservation Measures
- Resource Conservation and Development Loans
- Watershed Loans
- Soil and Water Loans to Individuals

Forest Service (FS)

- State and Private Forestry
- National Forest System

Science and Education Administration-Extension (SEA-E)

- Land and Water Conservation Education

Soil Conservation Service (SCS)

- Conservation Operations-Technical Assistance (COP)
- Watershed Operations
- Flood Prevention Operations
- Emergency Watershed Operations
- Resource Conservation and Development Program
- Great Plains Conservation Program
- Rural Clean Water Program
- Rural Abandoned Mine Program
- Resource Appraisal and Program Development

#### (2) USDA Supporting Programs for Soil and Water Conservation-(1980)

Economics Statistics Cooperative Service (ESCS)

Resource Economic Service
River Basin Planning Assistance

Forest Service (FS)

Forest Research
Science and Education Administration-Agricultural Research (SEA-AR)

Soil, Water, and Air Sciences Research

Science and Education Administration-Cooperative Research (SEA-CR)

Cooperative Research in Agriculture and Forestry

Soil Conservation Service (SCS)

Cooperative River Basin Studies
Watershed Planning
Inventory and Monitoring Program
Flood Plain Management Assistance Program
Soil Survey Program
Snow Surveys and Water Supply Forescasting
Plant Materials Center Operations

### (3) Purposes of USDA Soil and Water Conservation Programs (1979)

(Programs below pertain directly to desertification amelioration and/or control.)

Wind Erosion

- --Reduce wind erosion

Pasture/Range Productivity

- --Improve vegetation
- --Reduce damage by livestock
- --Increase soil moisture availability

Cropland Productivity

- --Improve soil fertility
- --Increase soil moisture
- --Improve soil fertility availability
- --Increase tillage and structure

Habitat Development

- --Improve fish habitat
- --Improve upland wildlife habitat

Irrigation Water Management

- --Improve distribution efficiency
- --Improve water use efficiency
- --Reduce irrigated land erosion
- --Improve quality of return flows
- --Reduce salt accumulation
- --Improve subsurface drainage

### Watershed Protection

--Reduce sheet erosion
--Increase channel stability
--Reduce gully erosion
--Reduce construction area erosion
--Reduce stream sedimentation
--Prevent water pollution

### Land Reclamation

--Restore mined areas
--Improve saline soils

### Flood Control

--Reduce upland runoff
--Reduce sedimentation
--Reduce floodwater erosion

### Drainage

--Reduce excess surface water
--Improve subsurface drainage

### Water Supply

--Increase soil moisture
--Increase ground water supply
--Increase surface water supply
--Prevent water pollution

## b. Other Federal Agencies

The information below is primarily from the 1980 Catalog of Federal Domestic Assistance, published by the General Accounting Office. This list of action programs in not all-inclusive nor is the order of presentation important.

### (1) Department of the Interior

Office of Surface Mining Reclamation and Enforcement
  --Abandoned Mine Land Reclamation Program

Water and Power Resource Service
  --Irrigation Systems Rehabilitation and Betterment
  --Small Reclamation Projects
  --Planning Program
  --Research Program
  --Environment Program
  --Environmental Education Program

Fish and Wildlife Service
  --Animal Damage Control Program
  --Environmental Contaminant Evaluation Program
  --Wildlife Restoration Program
  --Endangered Species Conservation Program
  --Habitat Preservation Program

Geological Survey
- --Mineral Resource Investigation Program
- --Mineral Fuel Investigation Program
- --Regional Geologic Investigation Program
- --Water Resource Investigation Program
- --Management of Natural Resources on Federal and Indian Lands
- --Geologic and Hydrologic Principles, Processes, and Techniques
- --Remote Sensing and Advanced Techniques
- --Land Use and Environmental Impact

National Park Service
- --National Environmental Study Areas Program
- --Management of the National Park System

Office of Water Research and Technology
- --National Water Research and Development Program

Bureau of Land Management
- --Planning and Inventory Coordination
- --Energy and Minerals Management
- --Renewable Resource Management
- --Recreation and Environmental Areas
- --Land and Realty Management

(2) Water Resources Council

--Water Resources Planning Program

(3) Environmental Protection Agency

--Air Pollution Control Program
--Water Pollution Control Program
--Solid and Hazardous Waste Management Program
--Environmental Protection
--Pesticides Control Program

(4) Department of Energy

--Research and Development in Energy Conservation

### 4. Conservation Practices

The following discussion is not intended to be an assessment of the technology available, but merely a description of the existing approaches to and Federally-funded practices for conservation of land and water resources. Some practices have already been discussed in Section II.D.

In the specific case of methods aimed at coping with arid land degradation problems, two general approaches utilizing available technology exist:

- modification of the physical conditions of a dry region to permit greater biological productivity (e.g., importation of water); and

- the strengthening and promotion of actions which maximize efficient use of the arid lands (e.g., careful introduction of new varieties of drought-resistant plants).

The effectiveness of any applied technology is generally dependent upon economic and environmental considerations and of people's expectations.

The following partial listing of technologies applicable to arid region problems is divided arbitrarily into (1) high-level, high-cost technologies for modifying the environment, and (2) intermediate, adaptive technologies.

(1) Environment-modifying technologies, such as:

- Interbasin water transfer facilities
- Exploitation of new water sources by such devices as deep drilling
- Desalinization plants
- Climatic modification through prolonged cloud seeding
- Major vegetation modification such as removal of phreatopytes

(2) Adaptive technologies, such as:

- Commercial cultivation of traditional desert plants such as jojoba and guayule
- Genetic improvement of crop species to produce greater resistance to salt or drought

A list of the soil and water conservation practices supported by Federal programs is presented here. This list was prepared by USDA in 1977.

Access road
Bedding
Brush Management
Channel vegetation
Chiseling and subsoiling
Clearing and snagging
Commercial fishponds
Conservation tillage system
Contour farming
Contour orchard and other fruit area
Cover and green manure crop
Critical area planting
Crop residue use
Dam, diversion
Dam, floodwater retarding
Dam, multiple-purpose
Deferred grazing
Dike
Diversion
Drainage land grading
Emergency tillage
Farmstead and feedlot windbreak
Fencing
Field windbreak
Firebreak
Fish raceway
Fish stream improvement
Fishpond management
Floodwater diversion
Floodway
Grade stabilization structure
Grassed waterway or outlet
Grasses and legumes in rotation
Grazing land mechanical treatment
Heavy use area protection
Hedgerow planting
Hillside ditch
Irrigation canal or lateral
Irrigation field ditch
Irrigation land leveling
Irrigation pit or regulating reservoir
Irrigation storage reservoir
Irrigation system
Irrigation system, tailwater recovery 2
Irrigation water conveyance
Irrigation water management
Land clearing
Land smoothing
Lined waterway or outlet
Livestock exclusion
Minimum tillage
Mole drain
Mulching
Obstruction removal
Open channel
Pasture and hayland management
Pasture and hayland planting
Pipeline
Planned grazing systems
Pond
Pond sealing or lining
Prescribed burning
Proper grazing use
Proper woodland grazing
Pumped well drain
Pumped plant for water control
Range seeding
Reclamation of surface mined land
Recreation land grading and shaping
Recreation trail and walkway
Rock barrier
Row arrangement
Sediment basin
Spoilbank spreading
Spring development
Stock trails and walkways
Streambank protection
Stream channel stabilization
Stripcropping
Structure for water control
Stubble mulching
Subsurface drain
Surface drainage
Terrace
Toxic salt reduction
Tree planting
Trough or tank

Vertical drain
Waste management system
Waste storage pond
Waste storage structure
Waste treatment lagoon
Waste utilization
Waterspreading
Well
Wildlife upland habitat management
Wildlife watering facility
Wildlife wetland habitat management
Windbreak renovation
Woodland improved harvesting
Woodland improvement
Woodland pruning
Woodland improvement
Woodland site preparation

### Principal Practices for Controlling Nutrient Loss (EPA, 1980)

- General: Eliminating excessive use of fertilizer

- Leaching Control: Timing nitrogen application
    - Crop rotation
    - Using animal wastes as fertilizers
    - Plowing-under green legume crops
    - Using winter cover crops
    - Controlling fertilizer release or transformation

- Control of Nutrient Runoff: Using legumes in pastures
    - Controlling surface application of fertilizers

- Control of Nutrient Loss by Erosion: Timing fertilizer plow-down

### Principal Practices for Controlling Runoff

- No-till planting
- Conservation tillage
- Sod-based rotation
- Winter cover crops
- Timing of field operations
- Plow-plant systems
- Contour listing
- Change in land use

A brief description of some grazing management systems that are at some point of research, development, or application follows:

1. The two pasture rotation ("alternate") ("South African Switchback") system of grazing offers little or no benefit from the standpoint of livestock gains or range improvement. Most authors doubt that the system is economically justifiable.

2. The three pasture rotation offers a slight disadvantage to livestock.gains and some advantage to increased pasture yields and improve pasture condition. Opinions appear to be divided on the economic feasibility of this system.

3. Rotations of 4 pastures or more - available literature was insufficient to support definite statements concerning this system. This system was studied with dairy cattle in a 6 pasture rotation and showed increase in livestock gains, milk production and grazing capacity. A four pasture study with cows and calves indicated that less utilization could be obtained with the same numbers under rotation.

4. Deferred rotation and rotational deferment - again there were too few research papers to support conclusions. Those reviewed showed an advantage in livestock gains. However, in recent years there have been numerous large-scale evaluation studies which indicate that livestock gains, pasture improvement in both vegetation and soils, and net returns are all benefited by these systems.

5. Rest-rotation - all authors appear to agree that this is the best long-range grazing system from all aspects of the livestock industry. The method appears to offer the greatest net returns per dollar of investment.

6. Deferred grazing - both research and evaluation studies of this practice are common. The key to range improvement apparently lies in the amount of rest provided the vegetation by deferment of grazing use during the growing season. Rate of improvement appears to be related to frequency and duration of rest. The fastest way to improve deteriorated range having sufficient cover for natural reseeding is through complete growing season deferment.

- Great Plains Conservation Program

What follows is a summary prepared by the Soil Conservation Service, USDA, on the Great Plains Conservation Program (GPCP).

- Authority for the GPCP

The Soil Conservation Service, U.S. Department of Agriculture, administers the Great Plains Conservation Program (GPCP) by authority of Public Law 1021, 1956, (84th Cong.) (16 U.S.C. 590 p), as amended. This authority terminates September 30, 1981.

- Purpose

This program gives assistance under 518 long-term contracts to land users in designated counties of 10 Great Plains states. Its purpose is to provide needed protection and improvement of soil, water, land, and wildlife resources of the Plains area, which is plagued with recurring drought and wind erosion problems. Installing complete conservation treatment and management systems on farms and ranches helps stabilize individual enterprises and consequently the local economy.

- Appropriations

Congress authorized appropriations of $600 million for the overall cost-sharing program. Cost-sharing payment cannot exceed $50 million in any program year. Of the annual GPCP budget, 60 percent is allocated for cost sharing of 33 soil and water conservation practices and the remaining 40 percent for technical assistance and administrative costs.

- Coordination

GPCP is coordinated with other Federal, State, and local agencies through established State and county GPCP committees. Soil Conservation districts review all contracts, set planning priorities, and serve on county GPCP committee.

- Practices Authorized for Cost Sharing in Most Counties -

Establishing permanent plant cover
Field stripcropping
Contour stripcropping
Reseeding grassland
Establishing trees or shrubs
Establishing permanent waterways
Terraces
Diversions
Grasslands mechanical treatment
Erosion control, detention, or sediment-detention dams
Grade-stablization structures
Streambank or shore protection
Diversion dams and spreader ditches
Reorganizing irrigation systems
Leveling land for irrigation
Constructing or improving dams, pits, or ponds for irrigation water

Lining irrigation ditches, canals, or laterals
Wells Developing springs and seeps
Dams, pits, or ponds
Pipelines
Controlling competitive shrubs
Fences
Critical area treatment
Irrigation tailwater recovery systems
Lagoons for disposal of animal wastes
Grading and shaping recreation land
Water storage facilities
Catchment basins
Shallow-water areas for wildlife
Holding ponds and tanks (pollution control)
Special practices

o Facts About the Great Plains -

Land area. The Great Plains has a total land area of 436 million acres. Of this acreage, 237 million acres is range and pasture; 122 million acres, cropland (16 million acres irrigated); 23 million acres, woodland; and 54 million acres other types of land. (See Figure 33.)

Climate date. Average annual precipitation ranges from 15 to 20 inches. The freeze-free period ranges from 110 to 210 days.

Principal products. Principal products are grass and hay, wheat (60 percent of the Nation's supply), cattle (30 percent of the Nation's supply), sheep (wool), cotton, and corn.

Number of farmers/ranchers. There are about 297,000 farmers/ranchers in the Great Plains area.

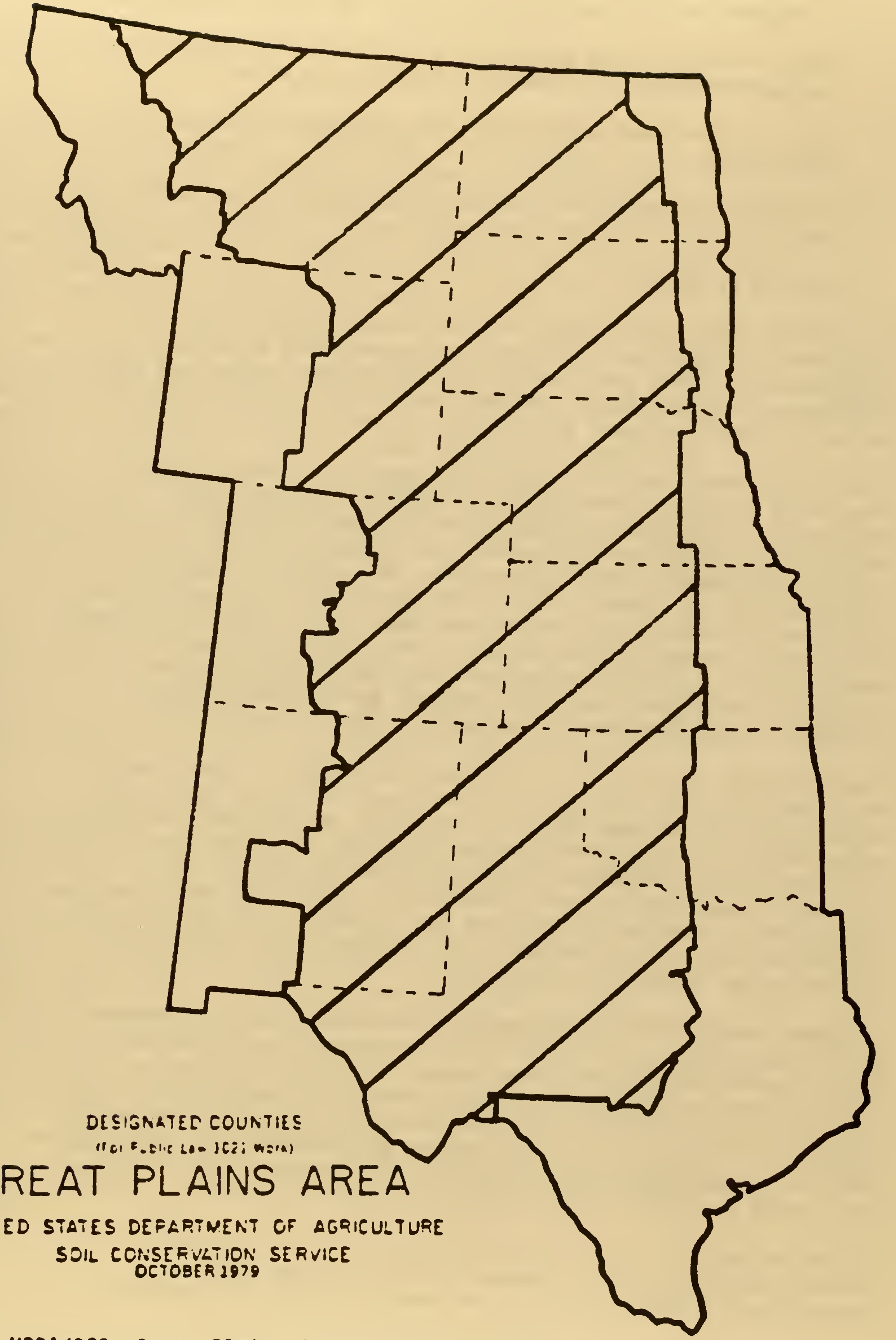
In June 1980, Congress extended the Great Plains Conservation Program (GPCP) for another 10 years. The Soil Conservation Service is studying ways to improve the program and is evaluating past, present, and future environmental, social, and economic impacts on the program. Some of the issues that will be addressed are listed below.

I. The impact of the Great Plains Conservation Program.

   A. Economic and social impacts, including the effect on the economic stability of farms and ranches in the Great Plains-a region of climatic extremes. Also, the effect on net farm and ranch profits, rural development, and small farms.

   B. Environmental impacts, including wildlife, water quality, and air pollution.

Figure 33



DESIGNATED COUNTIES
(For Public Law 1021 Work)
GREAT PLAINS AREA
UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
OCTOBER 1979

Source: USDA/SCS, Great Plains Conservation Program.

C. Impacts on the conservation of soil and water resources.

II. The need for any new program initiatives, direction, or management needed to improve program operations.

III. Any problems that have hindered or delayed achievement of GPCP goals.

IV. Possible alternatives of implementing GPCP in more efficient ways.

- The Vale Project

The Vale Project, the largest and most comprehensive range improvement project ever attempted, is often cited as a successful range rehabilitation project. The following is a summary of the USDA/Forest Service report Bulletin PNW 70 (1977) prepared by Harold F. Heady and James Bartolome.

This report evaluates the large-scale rangeland rehabilitation program in the Vale, Oregon District of the Bureau of Land Management. Sagebrush in combination with two grasses, the native perennial bluebunch wheatgrass and the introduced annual cheatgrass, dominates the vegetation on 90 percent of the 60- by 175-mile (100- by 180-km) area of the district. Cold winters and dry summers characterize the climate; annual precipitation averages from 7 to 12 inches (180 to 300 mm). About 24,000 persons live in the district, but they are concentrated in a small region of irrigated croplands. More than half the 419 ranchers in the district had grazing permits on Federal lands in 1975.

The history of livestock use and human settlement is discussed, beginning with the arrival of the fur trappers in the early 1800's. Major impacts came from travelers along the Oregon Trail, mining after 1863, and exploitive livestock grazing and homesteading from 1880 until 1934. Passage of the Taylor Grazing Act in 1934 initiated management of the public domain lands. The damage to the vegetation and soil was related to the types of use. The nature of the climax vegetation, the pattern of depletion or damage, and present range condition are inferred.

Congress appropriated approximately $10 million over an 11-year period beginning in 1963 to halt erosion, stabilize the livestock industry, and benefit other land uses. The money was used to control brush on 506,000 acres (205,000 ha), to seed 267,000 acres (108,000 ha) to desirable forage species, and to build over 2,000 miles (3,330 km) of fence, 1,600 water developments, and 463 miles (741 km) of pipelines. Supervision and management of the land uses were large parts of the Vale Program.

The major sagebrush control practices used either disk plows or aerially applied 2,4-D. Absence of native forage species necessitated seeding of introduced species, primarily crested wheatgrass. Attempts at reseeding without site preparation usually failed. Burning as a land treatment was not seriously considered.

Extensive sampling of treated areas revealed that most attempts at land rehabilitation succeeded. Treatments reduced brush, yet rarely were all brush plants killed. Reinvasion of sagebrush occurred in almost all areas, especially shortly after treatment. Where perennial grass stands were dense, cheatgrass was usually absent, and big sagebrush only reinvaded to about 25 percent cover. Under proper management, stands with brush no more than a quarter of the total cover should last indefinitely.

Livestock management formed an integral part of the Vale Program from its beginning. Currently, several hundred pastures are used in a myriad of different patterns of seasonal and rotational use. Of 144 pastures examined, 15 percent were grazed at the same time every year; 33 percent were rotated during the growing season and every year after seed had ripened. Systems emphasized deferment until seed ripening rather than no grazing for a whole year. The original plan to use crested wheatgrass primarily for the spring turnout pastures gradually changed during the course of the Vale Program. Crested wheatgrass seedings are now managed in the same patterns as the native bluebunch wheatgrass range. The Vale Program has increased the district's estimated grazing capacity from 285,000 animal unit months (AUM's) in 1962 to 438,000 AUM's in 1975. As only 8 percent of the total district was treated with brush control and seeding, most of the increase in grazing capacity resulted from improvement of native range. Improvement consisted of management opportunities and strategies provided by water development, fencing, brush control, and seedings.

These improvements were beneficial to other uses too. The nearly 2,500 wild horses in the area are rapidly increasing. James D. Yoakum in his August, 1979 Rangelands magazine article reports that the above improvements have resulted in a 100 % increase in the population of pronghorn antelope, while at the same time antelope in the surrounding adjacent rangelands have remained relatively static. The populations of other wildlife species such as bighorn sheep, sage grouse, and mule deer have also increased. Other wildlife species exhibited varied responses in relation to their particular habitat requirements, but none seems to have been damaged permanently by the land treatment. Water developments for livestock benefited waterfowl, and new fisheries were established. Range restoration, stimulated by the need for livestock production and made necessary by past abuses in livestock management, favorably served other range users as well. Except for soil damage from off-road vehicles, accelerated erosion has been essentially eliminated.

An economic analysis of the overall program reveals that at the current $1.51 fee for an AUM costs exceed benefits by about $5 million. At the $3 market value of an AUM in the region, costs benefits to local economy are not considered to exceed benefit to livestock by only $500.000. Many continuing costs are associated with upkeep of the physical improvements, especially water developments. Users, such as hunters, campers, rockhounds, and fishermen, have benefited from the project to a degree which may exceed the difference between livestock income and costs.

## H. Research Needs and Available Capabilities

Research is the process of acquiring knowledge and understanding, without which the present concern, the arrest and prevention of desertification, would have little success. Research must be in general effective and should provide not total, but sufficient knowledge to develop reasonable strategies to deal with a particular problem, in this case desertification. Research dealing with a problem-solving situation should yield the means to provide a number of alternatives from which to choose, a good understanding of all the aspects of the case, and an evaluation of the proposed solution in terms of actual and future conditions. It must be recognized that most desertification-related situations are highly complex in that they involve meeting the conditions and objectives of diverse groups, which are not all quantifiable to the same degree. Ultimately, the final choice of any action to alleviate the desertification problem must rest with the people. Thus, the decisionmaking process itself, one in which people are involved, needs considerable study.

To make intelligent decisions, managers and the public must know the consequences of alternative courses of action. In addition to the economic consequences of development and use of the resource base, the non-market costs and benefits of environmental protection and enhancement must also be evaluated, difficult as that may be.

Much research has been done, especially in the last 50 years, on conservation of the dry domain renewable resources, yet many unknowns still exist which, once uncovered, could influence and enhance man's capacity to live in and use the arid lands. The process of salt formation in soils, the process of evaporation from land surfaces, and the storage of water by plants are a few examples.

It is important to note that major breakthroughs are not required to make this type of research profitable. For example, water currently has a value of about $50 or $60 per acre-foot at the ground surface for irrigation in West Texas. Since approximately six million acres of land are irrigated, research that resulted in an average saving of one quarter of an inch of water per year on all irrigated land in the High Plains would conserve, each year thereafter, 125,000 acre-feet of water for a total value of $6 or $7 million at today's prices. Improved irrigation practices, new and improved soil conservation, and better control of noxious plants are but some of the benefits from research.

### 1. The Importance of Interdisciplinary Research

Desertification is fed by a number of single but complex problems. These "parts" must be addresssed discretely for the purpose of selecting suitable procedures to deal with the basic problem of how to manage and improve the resource base and to avoid desertification. There is no doubt that disciplinary research to help us better understand the arid system is necessary, but the fundamentally important holistic approach, generally missing, is needed as well. For this purpose studies on the relationships between the physical and the social systems, the organic and functional interactions among these systems, feedback mechanisms, ties between users and uses and between events that can affect, prevent, or control desertification can be better understood through research and improved flow of communication and information between various specialists, users, and decisionmakers.

Some of the areas interdisciplinary activities should focus on are:

- Arid and semiarid lands natural transformations;
- Desertification dynamics, processes, interactions, and feed-back mechanisms;
- Integrated data bank systems;
- Development of new or improved methods for measuring cost/benefit ratios;
- Long-range environmental effects of development of arid regions;
- Demographic studies related to the regional carrying capacity; and
- Monitoring systems and indicators of desertification.

Some of the benefits of undertaking this type of research are:

- to achieve a better understanding of the impact of human activities on the structure and dynamics of arid and semiarid biomes; activities that may result in desertification;
- to help solve the scientific, technological, and managerial problems raised by the development and usage of the natural resources in the arid regions where the desertification risk is high;
- to help in formulating natural resources policies that assess the special needs of the arid areas and that take into consideration the probability of desertification; and
- to facilitate the implementation of these policies by helping to attain specific objectives and keeping alternative options open.
- Providing technology transfer to under developed counties.

## 2. Sharing of Research Results

A distinct benefit of applying research results is the improvement of policy planning and management decisions at all levels of government and for all sectors of the economy. This particular goal cannot even be approached, however, if (a) decisionmakers are not mindful of the research or (b) the process of translating research results into policy decisions is either omitted, neglected, or of bad quality.

The central question then, is how to promote, enhance, and facilitate the flow of research results into policy decisions. One group that should be included in all steps of information gathering and dissemination is the decisionmakers themselves. The term "decisionmakers" is used here in its generic sense to connote people at all levels of government and in all sectors of the economy. It is worth emphasizing that research's role is to generate knowledge, not make policy per se.

The documenting and translating of research results into layman's language and the packaging and displaying of these results for their ultimate use by decisionmakers are both difficult, because many disciplines are involved, for example, in baseline determination and in the development and operation of predictive models. Each of the sciences and technologies involved has its own language, making communication difficult. More research is needed in this context.

### 3. Forecasting

Taking into account that arid and semiarid lands are especially susceptible to hydrological, climatic, productive, and other extremes, forecasting research is of great importance, especially for planning purposes.

Research in this area should include: improvement in predicting future climatic and atmospheric changes; forecasting weather conditions; understanding extreme events such as droughts, floods, heat waves, etc. by applying probabilistic and statistical procedures; developing water resource forecasting methodologies to include population dynamics and all factors affecting the supply and demand of water; and predicting economic and financial impacts and changes. Forecasts should be structured into short-term problem-solving and long-term research needs (on the order of 50 years ahead).

### 4. Agriculture and Other Land Use Interactions

While much research has been conducted on cultivation practices, more research aimed at conserving soil quality and moisture is warranted. The frequency, depth, and optimum times for plowing to conserve the greatest amount of soil moisture and nutrients and maximize crop yields need to be further studied. In like manner, the effectiveness of different types of terracing practices in utilizing available precipitation requires evaluation, particularly in view of rapidly changing energy costs.

One example of changing conditions and the need to know is that based on "conventional wisdom," cotton and grain surghum are the best money crops to raise in the South Plains of Texas. This may no longer be the case in the immediate future due to changes in price and availability of main agricultural inputs. Experimental plots should be utilized to investigate crops which grow well and produce high yields with less water, to develop drought-tolerant genotypes, or to find "big money" crops which could conceivably be grown in smaller quantities on fewer acres, and still generate the same dollar volume as crops presently grown. If these research results dictated cropping changes, then improved or different methods of financing, marketing, processing and transportation might need to be developed. Optimization of such developments would likewise require a substantial research effort.

Research on two main areas of rangeland quality and use deserve attention:

A. Rehabilitation and Management of Rangeland for Efficient Use of Soil and Water Resources

- o Learning how to rehabilitate deteriorated rangeland should permit restoration efforts that will reduce soil loss, improve water use, and increase productivity. Better and more economically efficient methods of brush and weed control, revegetation, management of insects, and improved agricultural techniques are needed.
- o Grazing systems mangement and nutritional practices must be developed that enable livestock to more efficiently use rangeland forage while improving or maintaining soil, water, and vegetation resources.
- o Range plants and animals with greater biological efficiency must be selected and bred. Measures of efficiency include fixation of atmospheric nitrogen, resistance to pests, photosynthetic rate, and the conversion of plant material to animal products with less water use and soil loss.

B. Inventory and Classification of Rangeland for Monitoring Soil and Water Resources

- o Learn how to evaluate the effects of soil erosion and water loss on range productivity. This information is needed to make better decisions about range management.
- o Determine how much soil erosion rangeland can endure before its productivity is adversely affected. Without this information, range managers cannot identify those sites where soil is being lost at a rate that threatens the future use of those sites.
- o Uniform procedures are needed to make inventories of range use, suitability, condition, and trends; and better procedures are needed to classify range

potential. These procedures would permit more precise application of the best management practices to conserve soil and water resources (Hedrick and Schuster, 1981).

Other topics of direct importance for desertification problems are: farmland depopulation problems; impacts of changes in land use practice on marginal lands; validation of new technologies in minimum tillage cultivation; energy-water budget in agriculture and other activities; impacts of salinization problems on agricultural activity; energy efficient production of food and fiber on rangeland.

### 5. American Indian Concerns

American Indian concerns should be considered in any research of arid and semiarid lands because of their historical perspective on the land, unique cultural background, legal and institutional systems, and special needs.

One research area of interest is the assessment of past irrigation projects on Indian arid and semiarid lands, to determine their relative success or failure. Research should also be conducted on crops which may be of interest on reservations, such as jojoba, guayule, mesquite, and saltbush for animal feed. The water quantity/quality requirements of each should be examined, as well as the market potential.

Studies should be conducted on the traditional methods of coping with the inherent variability of arid lands by the native populations, including strategies for dealing with risk and the modes of adaptation evolved. Other research activities that should be supported are:

- Studies on the attitudes and perceptions of Indian tribes which are the target of arid lands policies. The research should include an assessment of how the different tribes evaluate the potential return on and vulnerability of their investments, as well as how they perceive their options.
- Survey and evaluation of the performance of specialized institutions concerned with reducing risk (e.g., cooperative, credit institutions, storage facilities), allocating scarce resources (e.g., water rights and systems of land tenure), and curtailing production in bad years (e.g., soil banks and price support systems). The operation of such institutions can minimize the probability of resource degradation and consequent economic and social dislocation.

- Evaluation of the mechanisms for placing and maintaining arid lands problems on government agendas. Policies formulated under crisis conditions may focus on symptoms rather than underlying causes, and the political atmosphere conducive to policy making can quickly disappear. This may apply to Indian, public, and privately owned land.

### 6. Multi-Objective and Multi-Attribute Analysis

By virtue of their special characteristics, arid and semiarid lands call for a radical improvement in what is known as "economic analysis." It is an acceptable notion that all benefits and costs (monetary and non-monetary, commensurable and non-commensurable) should be considered in such an analysis, yet the quantification of these non-monetary and non-commensurable attributes has not always been possible. The idea of maximizing benefit minus cost, or minimizing cost, should be replaced by the notion of maximizing a host of (multiple) objectives, attributes, and criteria; yet the state-of-the-art has not been sufficiently advanced to make such quantification and analyses feasible. The importance of multi-objective analyses, where all objectives and attributes of the resource base are considered, should be recognized, especially in the case of dry lands where the desertification hazard is high. Research should be focused on such topics as:

- The quantification of such aspects as the irreversibilities associated with policy-, planning-, and management-decisions related to arid and semiarid lands; the sensitivity, stability, and responsiveness of dry lands to certain actions; the value of attributes such as esthetics, historical sights, and social well-being from local, regional and national perspectives; the social costs and benefits of migration from the "Frostbelt" to the "Sunbelt" regions, and others.

- The development of decision making methods and approaches for identifying, measuring, and integrating non-commensurable objectives and attributes associated with both the social and environmental (non-market values), and economic considerations. In other words, social and environmental objectives should be considered on a par with economic objectives.

Research results which would assist in realistically modeling, evaluating and analyzing arid and semiarid land issues and problems in a holistic approach should improve decisions related to desertification prevention and arrest at the local, State, regional and national levels; improve the quality, reliability, credibility, and the ultimate usability of mathematical models in planning and management of arid and semiarid lands; and reduce the present gap between modelers, systems analysts, and the scientific community in general, on the one hand, and the decisionmakers, practitioners, and managers on the other.

## 7. Risk and Impacts Analysis

The impacts of usage, planning, management, and policy decisions on arid and semiarid lands that could lead to desertification may be classified as either primary or secondary. Primary impacts are the expected risk (of any kind) or the intended results of these decisions. Secondary impacts are side-effects, unaccounted-for risk, or unintended results. Both types of impacts may have uncertainties associated with them.

Risk assessment is particularly desirable for arid and semiarid regions because of the recurring impact of natural events such as protracted and short-term droughts, destructive wind and hail storms, early and late frosts, and the impacts of human intervention together with marketing uncertainties. All costs and benefits of risk-taking at different levels of decisionmaking (Federal, State, local, elected or appointed officials, etc.) need to be determined and defined.

Economic models, such as input-output models, need to be refined and updated periodically. Little attention has been given to the problem of lessening the impacts of a major decline of irrigated agriculture, for example, or providing alternatives which might preserve the economy of a region which has reverted to dryland farming. If changes or shifts in the production of goods and services are to be required, a slow but evenly paced transition would not disrupt the economy as severely as would a sudden change. In addition to economic factors, the social, institutional, legal, and technological aspects should also be considered. The same is true if actions are necessary to maintain certain ongoing activities.

The research on the social-behavioral aspects in risk-benefit analysis should investigate what motivates successful local participation in development and anti-desertification efforts. A physical understanding of the arid and semiarid biomes and the risk of desertification, together with an analytical modeling capability displaying feedback loops of the climate-soil-plant-animal system, are needed as well.

A first step should be the development of a simple, macroscale (i.e., regional) representation of normal and stressed systems which follow a single critical flux (perhaps water in this case) and which takes into account the natural and induced uncertainties present in arid climates.

Some main topics for research in this area are:

- The quantification of risk so that it can be included in the evaluation and analysis, along with all other benefits and costs.

- The distributional effects of certain policies related to soil, water, and other resources conservation;

- Economic risks in the allocation and reallocation of water supplies;

- The legislative objectives of specific programs related to the use of resources in an arid environment, the institutional factors that prevent the achievement of these programs, and the risks involved; and

- An evaluation of the capacity to predict natural and manmade hazards in arid zones and the responsibility of local and State institutions to mitigate these hazards (especially the question of tort liability of governmental institutions).

### 8. General Observations

Many of the research topics discussed in this section, several presented in Appendix N, and others not treated in this document have been or are being researched to some extent. But in general it has been found that comprehensive and coordinated research from project-planning to application of results is lacking. Fragmentation is perpetuated by the problem-focused and mission-oriented quality of Federally-supported research. Another contributing factor is the absence of Federal organizations or programs enabling the integration of the dry land's resource base condition, demand, development planning, and management where it can be accomplished. At the State and local level the problem is similar. Current budgetary constraints may allow this situation to continue with the academic centers and governmental research institutions located in the field with first-hand experience, but unable to investigate these concerns in a holistic manner even when interested and able to address them. Another impediment to the observation, recording, and analysis of trends, causes, and effects of environmental transformations is the discontinuity of long-term research support. It is hoped that redirection of efforts and budgets will recognize the need for comprehensive and systematic research, and for coordination among and within research organizations for more efficient utilization of efforts and funds. This may be the time for State, regional, and national entities to jointly set research priorities that allow the best possible multiple-use of the Western States' resources for the good of the region and the Nation.

### 9. Available Capabilities

In addition to agency in-house capabilities, there are many Western institutions with organizations and personnel able and interested in doing research on desertification. (See Figure 34.) In fact, many institutions currently have some of this research included in

Figure 34

## Current Research Related to Desertification in the U. S.

| TOPIC AREA | SPECIFIC PROGRAMS | SPONSORING AGENCY | PARTICIPATING ORGANIZATIONS | FY 1981 BUDGET |
|---|---|---|---|---|
| CLIMATE CHANGE ANALYSIS | Drought Frequency | NOAA<br>NSF | NCAR | $217 Million |
| SOIL CONSERVATION | Erosion Control<br>Desalinization | USDA<br>DOI, OWRT | | $ 16 Million |
| WATER ALLOCATION | Supply Inventory<br>Recycling | DOI,USGS | | |
| LIVING RESOURCE MANAGEMENT | Grazing<br>Dry-land Agriculture | USDA<br>" | | |
| LAND USE | Changing Patterns | DOE, BLM | | |
| IMPACT ASSESSMENT | $CO_2$<br>Acid Precipitation | DOE, NOAA<br>EPA, USDA | National Atmospheric Depositition Program | $ 11 Million |
| ECOSYSTEM DYNAMICS | Grasslands<br>Deserts | NSF<br>NSF, DOE | | |

ongoing programs. The following list of institutions is not meant to be all-inclusive, but it provides a measure of the extent of the available expertise.

Federal Government Field Offices in the 17 Western States

- Department of Agriculture
  - Forest Service
    - Berkeley, California
    - Fort Collins, Colorado
    - New Orleans, Louisiana
    - Portland, Oregon
    - Ogden, Utah
  - Science and Education Administration
    - Fresno, California
    - Riverside, California
    - Fort Collins, Colorado
    - Columbia, Missouri
    - Fargo, North Dakota
    - College Station, Texas
    - Logan, Utah
    - Pullman, Washington
  - Soil Conservation Service
    - Phoenix, Arizona
    - Davis, California
    - Denver, Colorado
    - Boise, Idaho
    - Salina, Kansas
    - Bozeman, Montana
    - Lincoln, Nebraska
    - Reno, Nevada
    - Albuquerque, New Mexico
    - Bismarck, North Dakota
    - Stillwater, Oklahoma
    - Portland, Oregon
    - Huron, South Dakota
    - Temple, Texas
    - Salt Lake City, Utah
    - Spokana, Washington
    - Casper, Wyoming
- Department of Energy
  - San Francisco, California
  - Lakewood, Colorado
  - Kansas City, Missouri
  - Dallas, Texas
  - Seattle, Washington
- Environmental Protection Agency
  - San Francisco, California
  - Denver, Colorado
  - Kansas City, Missouri
  - Dallas, Texas
  - Seattle, Washington

Department of the Interior
- Fish and Wildlife Service
  - Denver, Colorado
  - Albuquerque, New Mexico
  - Portland, Oregon
- Geological Survey
  - Menlo Park, California
  - Denver, Colorado
- Bureau of Indian Affairs
  - Phoenix, Arizona
  - Window Rock, Arizona
  - Sacramento, California
  - Billings, Montana
  - Anadarko, Oklahoma
  - Muskogee, Oklahoma
  - Portland, Oregon
  - Aberdeen, South Dakota
- Bureau of Land Management
  - Phoenix, Arizona
  - Sacramento, California
  - Denver, Colorado
  - Boise, Idaho
  - Billings, Montana
  - Reno, Nevada
  - Sante Fe, New Mexico
  - Portland, Oregon
  - Salt Lake City, Utah
  - Cheyenne, Wyoming
- Bureau of Mines
  - Denver, Colorado
  - Spokane, Washington

- Office of Surface Mining
  - Denver, Colorado
  - Kansas City, Missouri

- Water and Power Resources Service
  - Sacramento, California
  - Denver, Colorado
  - Boise, Idaho
  - Billings, Montana
  - Boulder City, Nevada
  - Amarillo, Texas
  - Salt Lake City, Utah

## The 17 Western States

State and local departments and agencies for renewable resources conservation and management.

## Federal-State Cooperative Groups

Agricultural Experiment Stations
  (USDA and State universities)

Southwest Border Regional Commission
Four Corners Regional Commission
Old West Regional Commission
Pacific Northwest Regional Commission
Ozarks Regional Commission
   (Dept. of Commerce and State appointees)

Missouri River Basin Commission
Pacific Northwest River Basin Commission
   (WRC, USDI, and other Federal agencies; and State appointees)

## Regional Associations

National Association of Conservation Districts
Western Governors' Policy Office (WESTPO)
Western Water Council
Pacific Southwest Interagency Committee
Arkansas-White-Red Basins Interagency Committee

## Land Grant University Institutions

University of Arizona
Tucson, Arizona  85721
   Water Resources Research Center
   Institute of Arid Land Studies
   School of Renewable Natural Resources

University of California
Berkeley, California  94720
   Giannini Foundation of Agricultural Economics
   Kearney Foundation of Soil Science
   Water Resources Center
   Wildland Research Center
   Energy and Environment Division of Lawrence Berkeley Laboratory
Davis, California  95616
   Water Resources Center
   Institute of Ecology
Riverside, California 92502
   Dry Lands Research Institute

Colorado State University
Fort Collins, Colorado 80521
Environmental Resources Center
Water Resources Research Institute
Natural Resources Ecology Laboratory

University of Idaho
Moscow, Idaho 83843
Water Resources Research Institute

Kansas State Univeristy
Manhattan, Kansas 66506
Water Resources Research Institute
Food and Feedgrain Institute

Montana State University
Bozeman, Montana 59717
Water Resources Research Center
Institute for Applied Research

University of Nebraska
Lincoln, Nebraska 68503
Center for Agriculture, Meteorology, and Climatology
Institute of Agriculture and Natual Resources
Water Resources Center

University of Nevada
Reno, Nevada 89506
Water Resources Center
Desert Research Institute

New Mexico State University
Las Cruces, New Mexico 88001
Water Resources Research Institute
New Mexico Energy Institute

North Dakota State University
Fargo, North Dakota 58102
Water Resources Research Institute
Tri-College University Center for Environmental Studies

Oklahoma State University
Stillwater, Oklahoma 74074
Water Resources Research Institute
Center for the Application of Remote Sensing

Oregon State University
Corvallis, Oregon 97331
Water Resources Research Institute
Climatic Research Institute
Environmental Remote Sensing Application Laboratory

South Dakota State University
Brookings, South Dakota 57006
  Water Resources Institute
  Remote Sensing Institute

Texas Tech University
Lubbock, Texas 79409
  International Center for Arid and Semiarid Land Studies (ICASALS)

Texas A&M University
College Station, Texas 77853
  Water Resources Institute
  Earth Resources Institute
  Institute of Renewable Natural Resources

Utah State University
Logan, Utah 84322
  Center for Water Resources Research
  Ecology Center
  Institute of Outdoor Recreation and Tourism
  Insititue for Land Rehabilitation

Washington State University
Pullman, Washington 99163
  Water Research Center
  Environmental Research Center

University of Wyoming
Laramie, Wyoming 82071
  Water Resources Research Institute
  Research on Energy and Environment Laboratory
  Natural Resources Research Institute
  Rocky Mountain Institute for Energy and Environment

## 10. Some Examples of Ongoing Relevant Projects

Management and Improvement of Oakbrush Rangeland in the San Juan Basin
Vegetative Stabilization of Drastically Disturbed Lands

Improving Efficiency of Beef Cattle Production and Management Systems under Range Conditions in Eastern Colorado

Longterm Grassland Ecosystem Research

Short Duration Grazing Systems and Integrated Use of Wheat and Sorghums for Red Meat Production

Food/Habitat Relations of Livestock and Associated Animals in Range Ecosystems

Role of Photosynthesis and Carbohydrates in Range Plant Development, Defoliation and Environmental Stress

Energy Efficient Range and Complementary Forage and Beef Production Systems for the Great Plains

Stress Tolerant Crop Plants Derived from Plant Cell Cultures

Development and Evaluation of Vegetative Sampling on Areas Subject to Open Pit Mining

Effect of Public Grazing Lands on the Economy of Colorado

Improvement of Yield and Quality in Legumes and Grasses

Optimization of the Use of Range and Complementary Forages for Red Meat Production

Farm Irrigation Water Management

Geomorphic Controls on Diffuse Source Salinity in Western Colorado

Systems of Management of Optimum Water Utilization

Climate Data Information Service for Colorado

Meteorological Observations

Hydraulics of Water Resources Systems

Optimization of Water Delivery Systems

Groundwater Management and Investigations

Managing Mountain Meadows to Conserve Water and Improve Water and Herbage Quality

Reduction of Salt Damage to Crops, Soils, and Waters

(Source: Rocky Mountain Forest and Range Experiment Station, USDA, Fort Collins, Colorado)

## Section III. Desertification Status and Issues: The Local Assessement

### Introduction

Throughout the development of this assessment a large number of reports and publications were made available to the Desertification Assessment in the U. S. staff by officials and scientists of the Western States. A list of only those most pertinent to desertification topics follows. (These documents are available through the State organizations listed below.)

1. Indicators of Desertification in California, by the California Department of Conservation, February 1980.
2. A Report to the Honorable Richard D. Lamm of Drought Related Problems and Resources for the State of Colorado, by the Colorado Division of Disaster Emergency Services, 1977.
3. Summary of Findings and Recommendations for the Governor's Task Force on Idaho Agricultural Policy, July 1980.
4. Rangeland Resources of Idaho, by the Idaho Rangeland Committee and the College of Forestry, Wildlife, and Range Sciences, University of Idaho, September 1978.
5. Groundwater Quality Atlas of Nebraska, USGS Resource Atlas No. 3, by R. A. Engberg and R. F. Spalding, 1978.
6. RCA Appraisal 1980, by the New Mexico Soil and Water Conservation Division, February 1980.
7. Oregon's Natural Resource Conservation Commitment 1980-1984, by the Oregon Association of Conservation Districts.
8. The Vale Rangeland Rehabilitation Program: The Desert Repaired in Southeastern Oregon, USDA Forest Service Bulletin PNW-70, by H. F. Heady and J. Bartolome.
9. Western South Dakota River Basins, USDA, August 1979.
10. Assessment of Desertification in Texas, by the Texas Interagency Task Force on Desertification, 1980.
11. Desertification in Texas, by J.L. Schuster, 1980.
12. Groundwater Resources of the Texas High Plains: State-of-the-Art and Future Research Needs, by Sweazy, Urban, Reeves, and Whetstone, Texas Tech University Water Resources Center; for National Science Foundation, November 1978.

13. Continuing Water Resources Planning and Development for Texas, by the Texas Water Development Board, May 1977.

14. Texas Trends, by the Texas 2000 Project, Governor's Office, August 1980.

15. Utah's 1977 Drought, Water Resources Planning Series UWRL/P-78-07, by the Utah Water Research Laboratory, Utah State University, December 1978.

16. Palouse Cooperative River Basin Study, USDA, 1978.

A few States (notably California and Texas) took the time and effort to specially prepare reports on desertification processes in their State. These have been extremely useful to development of the U.S. desertification document and will continue to serve as valuable information to the States themselves. These specially-prepared reports are available as Background Material through the Desertification Assessment in the U.S. project.

Information contained in both types of report, in addition to State-supplied data for the Western Governor's Policy Office (WESTPO), has been summarized and is presented together with responses from Federal field organizations to a DAUS questionnaire, in Section III.

## A Survey of States' Views

### 1. Background

In November 1980 the Western Governors' Policy Office (WESTPO) was commissioned by the Bureau of Land Management to prepare a report summarizing and analyzing sampled Western reactions to, and concerns about, desertification. The report is based on:

- a survey conducted in December 1980 and January 1981 of individuals and organizations in 17 Western States, including government officials, representatives of land-user groups and other interest groups, and members of research organizations and institutions;
- meetings and discussions held during the past two years with numerous individuals in the West, including many State and local officials responsible for creating and executing resource management policy; and
- a review and analysis of literature and other material concerning desertification and other conditions related to arid and semiarid lands.

Throughout the development of this assessment it was found that the term "desertification" has been generally misunderstood or preceived as meaning only the terminal stage or the irreversible state of the process. For purposes of the survey, WESTPO felt that the substitute term "environmental transformation" would avoid these problems and better relate the naturally-induced imbalances, the resilience of the ecosystem, and the contribution of technology, to human-induced changes.

## 2. Summary of Survey Findings

Individuals were asked to:

- describe major environmental transformations during the last 50 years;
- characterize the natural and manmade forces producing these transformations;
- identify the general effects of such transformations;
- describe existing measures for coping with these transformations;
- evaluate the effectiveness of such measures; and
- list by priority needed additional research or action.

Causes and effects of environmental transformations are very closely interrelated, and in many instances the two are difficult to distinguish. Respondents identified the following causes and effects of environmental change:

- rapid population migration into the region due primarily to employment opportunites, recreational opportunities, and favorable climate and environment;
- conversion of farmland to urban uses, and subsequent conversion of dryland and range to irrigated farmland;
- depletion of underground water, and increased erosion, soil salinity, and food production costs due to the expansion of irrigation agriculture into "marginal" farmland;
- increased national and international demand for range and agricultural products;
- acceleration of national demand for the development of energy, mineral, and other natural resources;

- poor range management practices, including overgrazing; and
- less-than-average precipitation, including drought conditions.

Participants in the survey were asked to identify and evaluate existing measures for addressing the environmental transformations (e.g., government programs, private practices) and to recommend additional effort or actions needed. The following measures, many of which are currently being executed, were identified by respondents as being the most effective:

- adoption of improved water conservation practices, including more efficient irrigation techniques, through establishment of stronger incentives;
- introduction of "drought-resistant" or low-water crops;
- expansion of water storage capacities;
- revegetation of rangeland;
- adoption of growth management and land-use regulations to encourage water-conserving development and settlement patterns;
- continuation of studies and research on improved land management practices;
- continuation of statistical, extension, and soil conservation services by the Federal Government;
- examination and possible revision of State water legislation.

## 3. Conclusions

There is an overriding concern about the magnitude and pace of external demands on the West's resources. These pressures include:

- in-migration from other regions of the country;
- development of energy resources and strategic non-energy minerals;

- production of agricultural commodities for domestic and export markets;

- demands to retain the region's environmental amenities as a national wildlife and recreation resource.

These exogenous forces have reduced the effectiveness of existing management measures and present major challenges to develop more effective and responsive resource management strategies.

Water is the crucial factor in the future of the West; its availability or scarcity affects every aspect of the human and physical environment and determines both present and future land management decisions. Western States require a broader policy framework than "desertification mitigation" in order to respond to environmental transformations in the region. Figure 1 represents the relationship of water to the causes and effects of changes in the environment and places "desertification" in a broader and more useful context. It points out that aridity and drought conditions set up a sequence of naturally induced environmental transformations that can cause ecological change and degradation. Thus, man-induced stresses are but a part of a bigger picture.

Nevertheless, it has been recognized that the arid West has been transformed from a pristine environment to the "breadbasket" and "energy basket" of the Nation. In addition, demands for military, mineral, and recreational use have been placed on the area. Therefore, water and other resource availability and management must become key factors in understanding and addressing the forces of change in this particular environment.

# APPENDICES

## Appendices - Table of Contents

A. References and Selected Literature..........125
B. Glossary..........152
C. Abbreviations, Acronyms, and Conversions..........164
D. Geographical Regions..........167
E. Ecological Regions..........173
F. Climatological Conditions of Arid and Semiarid Lands..........179
G. Soil..........185
H. Water..........187
I. Effect of Social Structure..........201
J. Economic Concerns..........208
K. Federal Institutional Responsibility..........216
L. Federal Legislation on Land and Natural Resources..........230
M. Monitoring Programs..........241
N. Research Needs..........253
O. Working Groups and Staff..........272

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## Appendix B: Glossary

### - A -

Abandonment - An intentional relinquishment of a known right. Concurrence of relinquishment of possession, and intent not to resume it for beneficial use. Neither alone is sufficient.

Acre-foot - The quantity of water required to cover 1 acre to a depth of 1 foot.

Agricultural Land Classification -

Cropland - Land used primarily for the production of cultivated crops, close-growing crops, and fruit and nut crops.

Pastureland - Land used primarily for the production of domesticated forage plants for livestock.

Rangeland - Land on which the natural potential (climax) plant cover is principally native grasses, grasslike plants, forbs, and shrubs. It includes natural grasslands, savannahs, certain shrubs and forb lands, most deserts, tundra, alpine communities, coastal marshlands, and wet meadows. It also includes lands that are revegetated naturally or artificially and are managed like native vegetation. It is not cultivated, drained, irrigated, or mechanically harvested.

Albedo - The amount of solar radiation reflected by a surface.

Atmospheric albedo - The amount of radiation reflected by clouds and other particles in the atmosphere.

Surface albedo - The amount of radiation reflected by the surface of the earth.

Alkalinization - Process by which alkali salts accumulate in the soil.

Allotment - An area designated for the use of a prescribed number and kind of livestock under one plan of management. It generally consists of public lands but may include parcels of private or State-owned lands. The number of livestock and season of use are stipulated for each allotment. An allotment may consist of several pastures or only one pasture.

Alluvial - Related to sediment deposited by streams.

Alluvial soil - A type of soil that develops from waterborne sediment; azonal.

Animal unit - The range livestock measurement equivalent to one mature (1,000 lb.) cow or the equivalent based upon average daily forage consumption of 26 lbs. dry matter per day, usually one horse, five sheep, etc.

Animal unit month (AUM) - A measure of forage or feed required to maintain one animal unit for a period of 30 days.

Aquifer - A saturated underground body of rock or similar material capable of storing water and transmitting it to wells or springs.

Aquifer recharge - The process of refilling an aquifer from which water has been drawn.

Arid lands - Areas where annual evapotranspiration loss equals or exceeds annual precipitation; where a deficiency of water prevails; where precipitation varies widely in time and space. Most arid areas have warm or hot temperatures in at least one season with the diurnal (daily) temperature variance wide. Wind and abundant sunlight are a common characteristic to arid lands.

The classification of arid lands is semiarid, arid, or extremely arid. On the average, semiarid lands receive 10-25 inches of annual precipitation, arid lands 5-10 inches, and extremely arid lands less than 5 inches. The United States contains land in each of the three classifications.

Artesian - A condition in which the water table in the unconfined ground area, through which recharge takes place, is situated at a higher elevation than the confined area of the aquifer. If a well is located in the confined aquifer, the well water will rise to the level of that in the unconfined area.

## - B -

Biomass - The total amount of living plants and animals above and below ground in a particular habitat or area.

Biota - The flora and fauna of a region.

Browse - As a verb, to consume, or feed on or eat (a plant); as a noun, the tender shoots, twigs, and leaves of trees and shrubs often used as food by cattle, deer, elk, and other animals.

Browse line - A well-defined height to which browse has been removed by animals.

Brush - Vegetation consisting primarily of bushes and shrubs usually undesirable for livestock or timber management. It may sometimes be of value for browse or for watershed protection.

## - C -

Carrying capacity - The maximum stocking rate possible without inducing damage to vegetation or related resources. It may vary from year to year on the same area due to fluctuating forage production.

Center pivot - Irrigation system in which a radial arm supporting sprinkler heads rotates on large wheels around a central pivot which is usually over a well. The result is a circular irrigated field usually one section (640 acres) in size.

Channel - That part of a natural stream where water normally flows or a ditch excavated for the flow of water.

Channelization - The process by which a natural stream is converted into a ditch for the ostensible purpose of flood control.

Clearcutting - A method of cutting that removes the entire timber stand from the area cut.

Compaction - Process by which soil is packed tightly, losing porosity.

Conservation tillage - A form of noninversion tillage that retains a protective amount of residue mulch on the surface throughout the year. Some conservation tillage methods are: minimum tillage, no till, reduced tillage, stubble-mulch tillage, chisel planting, and till planting.

Consumptive use (of water) - Withdrawing water from a supply which, because of absorption, transpiration, evaporation, or incorporation in a manufactured product, is not returned directly to a surface or groundwater supply; hence, water is lost for immediate further use.

Non-consumptive use (of water) - The act or process of using water that does not reduce its volume; the utilization of water in the process of producing a product which results in no deterioration of quantity or quality or transformation of water; primarily involves instream flow.

Contour farming - Plowing, cultivating, and harvesting crops along the contour of the land rather than up and down the slope; an effective technique for controlling soil erosion.

Cost-benefit analysis - Comparison of the expected benefits of a project with the anticipated costs of that project.

Cover - The material covering the soil and providing protection from, or resistance to, the impact of raindrops and the energy of overland flow, and expressed in percent of the area covered. Composed of vegetation, litter, small rock, and large rocks. These may be lying on or within 20 feet of the ground surface.

Cover crop - A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production or between trees and vines in orchards and vineyards.

Cropland - See Agricultural Land Classifications.

## - D -

Deferred grazing - The delay or discontinuance of use of livestock grazing on an area for an adequate period of time to provide for plant reproduction, establishment of new plants, or restoration of vigor of existing plants.

Deposition - The process by which soil particles are transported by wind and/or water and are deposited in a place other than that of origin.

Desert pavement - The stony surface of some deserts caused by excessive erosion of the thin topsoil by occasional heavy rainfall or by wind erosion.

Diurnal - by day.

Drainage - Gradual outflow of water by means of surface or subsurface water movement.

Drainage basin - The land area from which water drains into a river. Also called "catchment area," "watershed," or "river basin."

Drought - The condition of moisture deficit sufficient to have a temporal adverse effect on vegetation, animals, and man over a sizable area (Warrick, 1975).

. . . A prolonged lack of precipitation less than average (Russell, 1970).

. . . A prolonged weather condition characterized by deficient moisture and increased evaporation.

. . . Climatic excursion involving a shortage of precipitation sufficient to adversely affect crop production or range productivity (Rosenberg, 1979).

## - E -

Ecosystem - A community of organisms in relation to their environment including both the living and non-living constituents, and forming an interacting system inhabiting an identifiable space.

Environment - The surrounding conditions, influences, or forces that affect or modify an organism or an ecological community and influence its development or existence.

Ephemeral stream - A stream which flows only after rainfall or snowmelt; or which does not flow continuously.

Erosion - The process by which portions and particles of soil are broken away and transported to another location by agents such as wind or water.

Accelerated erosion - Erosion much more rapid than normal, primarily resulting from the influence of the activities of man and animals or natural events such as fire that expose the surface.

Geologic erosion - The normal or natural erosion caused by geologic processes acting over long geologic periods.

Gully erosion - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from the narrow area to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.

Natural erosion - Wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. Synonymous with geologic erosion.

Normal erosion - The gradual erosion of land used by man which does not greatly exceed natural erosion.

Rill erosion - An erosion process in which numerous small channels of only several inches in depth are formed.

Sheet erosion - The removal of a fairly uniform layer of soil from the land surface by runoff water.

Splash erosion - The spattering of small soil particles caused by the impact of raindrops on soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.

Erosion pavement - A layer of coarse fragments of gravel and stones on the surface of the ground, remaining after the removal of the fine particles by erosion.

Evapotranspiration - Loss of water from the soil both by evaporation and by transpiration (passage as vapor through membranes) by plants living thereon.

## - F -

Forage - Vegetative material produced by plants and used as food by animals.

Forb - A small broadleaf plant; weed.

## - G -

Grasses - Narrow-leaved plants often used as forage.

Tall grass - Species such as bluestem, Indian grass, and wheatgrass generally ranging in height from 3 to 8 feet.

Short grass - Species such as buffalo grass and grama, generally ranging from 0.5 to 2 feet in height.

Grazing capacity - See Carrying Capacity.

Grazing district - An administrative subdivision of the rangelands under jurisdiction of Federal or State management.

Groundwater mining - The practice of withdrawing from an aquifer at a rate in excess of net recharge. This overdraft eventually causes the underground supply to become exhausted or the water table to drop below economic pump lifts.

Gully - A channel cut by concentrated runoff through which water commonly flows only during or immediately after heavy rains or during the melting of snow. A gully is deep enough to interfere with, and not be obliterated by, normal tillage operations.

Gully reclamation - The "mending" of a gully by either physical methods (check dams of boulders or cement) or vegetational means (planting of rapidly growing shrubs on the slopes).

- H -

Hardpan - A hardened or cemented soil layer. The sandy, loamy, or clayey soil material is cemented by iron oxide, silica, calcium carbonate, or other substances. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not slake in water.

Horizon - The distinctive horizontal layers that are apparent in vertical soil cross-sections.

Humus - Accumulated decomposed debris of plant stems, leaves, and roots forming the organic material in soils.

Hydrologic cycle - The circulation of water from the sea, through the atmosphere, as precipitation to the land, and then (with many delays) back to the sea by overland and subterranean routes, or directly back into the atmosphere by evaporation and transpiration.

- I -

Impact - A change in the ecosystem resulting from or accelerated by human action.

Infiltration - The passage of water into the soil by moving through pores and interstices.

Instream use - Use of water which does not require withdrawal or diversion from its natural watercourse. For example, the use of water for navigation, waste disposal, recreation, and support of fish and wildlife.

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Interbasin transfer - The physical transfer of water from one watershed to another. On a large scale, the transfer of large quantities of water from one major river to another.

Intermittent stream - One which flows only during the wet season but which dries up during the dry season.

Interstices - Spaces between solid rock particles and fragments which affect the occurrence of groundwater.

Invader - A plant species that was absent or present in only very small amounts in the undisturbed portions of the original vegetation but will become established therein under conditions of disturbance or continued overuse.

Inventory - A listing of the resources (and location), natural and manmade, which characterize a land area. It is a static picture of the basic resource situation, describing the quantity and quality of such attributes of land as geology, vegetation, soil, and water resources. A resources inventory provides a data base which then can be periodically updated, and trends illustrated, by suitable monitoring techniques.

Irrigation water management - The use and management of irrigation water whereby the quantity of water used for each irrigation is determined by the water-holding capacity of the soil and the need of the crop. The water is applied at a rate and in such manner that the crop can use it efficiently and no significant erosion occurs.

## - K -

Key species - (1) Forage species whose use serves as an indicator of the degree of use of associated species. (2) Those species which must, because of their importance, be considered in the management program.

## - L -

Land capability classification - The quality of soil resources for agricultural use without permanent damage is commonly expressed in land capability classes and subclasses which show, in a general way, the suitability of soils for most kinds of field crops. Soils are grouped according to their limitations when they are used for field crops, the risk of damage when they are used, and the way they respond to treatment.

Capability classes, the broadest groups, are designated by Roman numerals I through VIII. The numerals indicate progressively-greater limitations and narrower choices for practical use. The classes are defined as follows:

Class I soils have few limitations that restrict their use.
Class II soils have moderate limitations that reduce the choice of plants.
Class III soils have severe limitations that reduce the choice of plants.
Class IV soils have very severe limitations that reduce the choice of plants.

Class V soils are not likely to erode but have other limitations, impractical to remove, that limit their use.
Class VI soils have severe limitations that make them generally unsuitable for cultivation.
Class VII soils have very severe limitations that make them unsuitable for cultivation.
Class VIII soils and landforms have limitations that nearly preclude their use for commercial crop production.

Capability subclasses are soil groups within one class; they are designated by adding a small letter, "e," "w," "s," or "c," to the class numeral, for example, IIe. The letter "e" shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; "w" shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); "s" shows that the soil is limited mainly because it is shallow, droughty, or stony; and "c," used in only some parts of the United States, shows that the chief limitation is climate that is too cold or too dry.

Litter - The uppermost layer of organic debris composed of freshly fallen or slightly decomposed organic materials; includes all undecomposed dead organic matter lying or standing within 20 feet of the ground surface. Litter includes lichens and moss having less than 1/16 inch growing on litter.

## - M -

Macroclimate - The climate of a large geographical area.

Management - The decisionmaking process in the presence of uncertainty, that involves the manipulation of one or more of the dependent and/or the controlling factors.

Mesic - Characterized by, relating to, or requiring a moderate amount of moisture.

Microclimate - The climate of a localized and specific area.

Minimum tillage - Limiting the number of cultural operations to those that are properly timed and essential to produce a crop and prevent soil damage.

Monitor - To scrutinize or check systematically with a view to collecting certain specified categories of data.

Monoculture - Raising crops of a single plant variety, cultivated as well as natural.

Multiple use - In the case of resources, development of a particular resource to serve two or more purposes simultaneously.

### - N -

Natural resource - Any component of the natural environment, such as soil, water, rangeland, forest, or wildlife that man can use to promote his welfare. A natural resource can be renewable or nonrenewable.

Nonpoint source - Refers to pollution discharge from numerous scattered sites throughout a given area, transported to surface and groundwaters through diffuse routes.

### - O -

Off-road vehicle (ORV) - Any motorized vehicle designed for or capable of cross-country travel on or immediately over land, water, sand, snow, ice, marsh, swampland, or other terrain.

Overgrazing - Consumption of vegetation by herbivores beyond the endurance of a plant to survive; continued overuse creating a deteriorated range.

### - P -

Pastureland - See Agricultural Land Classification.

Pedogenic - Related to soil formation.

Perennial stream - A watercourse which flows constantly throughout the year.

Permeability - The ease with which gases, liquids, or plant roots penetrate or pass through a bulk mass of soil or a layer of soil.

Phreatophyte - A deep-rooted plant that obtains its water from the water table or the layer of soil just above it.

Point source - Refers to discharge of pollution from discernible, confined, and discrete conveyance areas.

Public land - land in federal ownership.

Public use - Includes but is not necessarily limited to the following: stockwatering, human consumption, range improvement, protection and management, agricultural irrigation of native plants, fish and wildlife, fire, recreation, flood control, erosion control; does not include mining claims, mill sites, desert land entries, and Carey Act entries.

### - R -

Range condition - The present productivity on a range site as related to the potential natural plant community for that site. Range condition is expressed as excellent, good, fair, or poor, on the basis of how much the present plant community has departed from the potential.

Reclamation - Rendering land suitable for cultivation.

Rehabilitation - Restoration of partially or totally lost biological productive capability.

Relative humidity - The ratio of absolute humidity to the maximum possible density of water vapor in the air at the same temperature.

Remote sensing - The science of acquiring data about objects from measurements recorded by various sensing instruments operating at a considerable distance from their target. Remote sensing of the environment is accomplished by any of a number of cameras and scanners operating in different bands of the electromagnetic spectrum. They are carried aboard aircraft or satellites and collect data about the earth's surface, near-surface, and atmosphere.

Retorting - Operation by which substances are extracted, distilled, or decomposed by heat.

Rill - A small, intermittent watercourse with steep sides, usually only a few inches deep and, hence, no obstacle to tillage operation.

Riparian habitat - Habitat related to or located along a watercourse.

Roil - To make muddy or cloudy by stirring up sediment.

Runoff - The portion of precipitation which is not absorbed by the soil and which flows into surface waters.

- S -

Salinization - The process by which evaporation of salty water leaves a salt accumulation in the soil, which renders the soil unsuitable for crop production.

Scour - To abrade and wear away terrace, diversion channels, or streambeds.

Sedge - Grasslike plant having solid rather than hollow stems.

Sediment - Soil or mineral material transported by water and deposited in streams or other bodies of water.

Seepage - Water which passes into the soil from under a reservoir or other water body.

Site-specific - Refers to phenomena which occur under certain conditions at a particular site, but which would not necessarily occur at another site.

Slash and burn agriculture - A method of agriculture practiced in forests in which the land is cleared by cutting and burning. It is then planted and harvested, and after it loses its productivity, it is allowed to return to forest to regain productivity while another plot of forest is cleared and utilized.

Specific yield - The volume of water which drains from a soil under the force of gravity. It is normally expressed as a percentage by volume of the drained material and represents the effective porosity or the effective storage of the water-bearing material.

Soil deterioration - Loss of potential productive capacity of a soil that results from destructive processes accelerated by the activities of man, for example, through soil erosion and waterlogging.

Soil moisture zone - Depth of soil from which plant roots extract water.

Soil order - Ten orders are recognized. The properties used to differentiate among orders are those that reflect the kind and degree of soil-forming processes that have taken place. Each order is identified by a word ending in sol. An example is Mollisol.

Soil profile - A cross-sectional view of a particular soil type in which the characteristic layers or horizons are well represented.

Soil structure - The arrangement or grouping of the soil's primary particles into granules or aggregates; a soil with good structure has a spongy or crumbly quality with an abundance of pores through which water and oxygen can move.

Soil texture - The size of the individual soil particles; the four textural categories ranging from the smallest to the largest sized particles are clay, silt, sand, and gravel.

Standard Metropolitan Statistical Area (SMSA) - An integrated economic and social unit with a large population nucleus. Each SMSA includes the county in which the central city is located, and adjacent counties that are metropolitan in character and economically and socially integrated with the county of the central city.

Streamflow - The discharge in a surface stream course.

Strip cropping - An agricultural practice in which an open row crop (potatoes, corn, cotton) is alternated with a cover crop (alfalfa, clover) to minimize soil erosion.

Stubble-mulching - Leaving the stubble of crops or crop residue essentially in place on the land as a surface cover during fallow and the growing of a succeeding crop.

Subsidence - Process by which the soil level is lowered by overdraft of groundwater, oil, etc.

## - T -

Terracing - A soil conservation technique in which steep slopes are converted into a series of broad-based "steps"; the velocity of runoff water is thus reduced and soil erosion is arrested.

*Transpiration* - The process in which plant tissues give off water vapor to the atmosphere.

*Turbidity* - The cloudy condition caused by suspended solids in a liquid.

## - U -

*Ungulates* - Hoofed mammals such as horses, cattle, and deer.

*Urban and built-up areas* - Human settlement and built-up areas of more than 10 acres, including industrial sites, railroad yards, cemetaries, airports, golf courses, institutional and public administration sites, and similar areas.

## - W -

*Water depletion* - Water consumed that is irrecoverable to the hydrologic cycle or system.

*Waterlogging* - A condition in which the water table rises to near the surface of the soil.

*Watershed* - The total area drained by a particular stream; may range from a few square miles to thousands of square miles.

*Water table* - The upper level of an underground water body.

*Wildlife habitat* - All elements of a wild animal's environment which the animal needs to normally and naturally complete its life cycle. These elements are usually described as food, cover, water, and living space, but included here are all the conditions and items needed to satisfactorily produce the above four elements in the amounts, qualities, and juxtapositions which the animal requires to complete its life cycle.

*Withdrawal* - Water taken from a surface or groundwater source for offstream use.

## -X-

*Xeric* - Characterized by, relating to, or requiring only a small amount of moisture.

*Xerophytic* - The quality of plants which are structurally adapted for life and growth with a limited water supply.

# Appendix C: Abbreviations, Acronyms, and Conversions

## Common Abbreviations

| | |
|---|---|
| acre | ac |
| acre-foot | af |
| acre-foot per year | af/yr |
| average | avg |
| billion gallons per day | bgd |
| capita | cap |
| cubic foot | $ft^3$ |
| cubic food per second | cfs |
| cubic meter | $m^3$ |
| cubic yard | $yd^3$ |
| dollars | dol. |
| foot | ft |
| gallon | gal |
| gallons per capita per day | gcd |
| hectare | ha |
| inch | in |
| inches per year | in/yr |
| kilogram | kg |
| kilometer | km |
| kilowatt | kw |
| kilowatt-hour | kwh |
| liter | l |
| megawatt | mw |
| mile | mi |
| millimeter | mm |
| million | mil. |
| million acre-feet | maf |
| million acre-feet per year | maf/yr |
| million gallons per day | mgd |
| month | mo |
| number | no. |
| parts per million | ppm. |
| percent | % |
| square mile | sq mi |
| thousand | thou. |
| year | yr |

# List of Abbreviations and Acronyms

AAAS - American Association for the Advancement of Science
AID - Agency for International Development
ASCE - American Society of Civil Engineers

BIA - Bureau of Indian Affairs, Department of the Interior
BLM - Bureau of Land Management, Department of the Interior
BuCensus - Bureau of the Census, Department of Commerce
BuRec - Bureau of Reclamation, Department of the Interior

CEQ - Council on Environmental Quality

DAUS - Desertification Assessment in the United States
DOD - Department of Defense
DOE - Department of Energy

EIS - Environmental Impact Statement
EPA - Environmental Protection Agency
ERDA - Energy Research and Development Administration

FAO - Food and Agriculture Organization, United Nations
FWS - Fish and Wildlife Service, Department of the Interior

GAO - General Accounting Office, Congress of the United States
GSA - General Services Administration

ICASALS - International Center for Arid and Semi-Arid Land Studies, Texas Tech University
IUCN - International Union for Conservation of Nature and Natural Resources

MAB - Man and the Biosphere (a United Nations program)

NAS - National Academy of Sciences
NOAA - National Oceanic and Atmospheric Administration, Dept. of Commerce
NRI - National Resources Inventories, Soil Conservation Service, USDA
NSF - National Science Foundation (U. S. Govt.)
NTIS - National Technical Information Service, Department of Commerce

OSM - Office of Surface Mining and Reclamation Enforcement, Department of the Interior
OSTP - Office of Science and Technology Policy, Executive Office of the President
OWRT - Office of Water Research and Technology, Department of the Interior

RCA - Resources Conservation Act, Soil Conservation Service, USDA
RPA - Resources Planning Act, Forest Service, USDA

SCS - Soil Conservation Service, USDA
SEA - Science and Education Administration, USDA

UNEP - United Nations Environmental Program
UNESCO - United Nations Educational, Scientific, and Cultural Organization
USDA - United States Department of Agriculture
USDC - United States Department of Commerce
USDI - United States Department of the Interior
USGS - United States Geological Survey, Department of the Interior

WESTPO - Western Governors' Policy Office
WPRS - Water and Power Resources Service (formerly BuRec), Department of the Interior
WRC - Water Resources Council

## Approximate Conversion Factors

1 hectare (ha) = 2.47 acres

1 square mile (sq mi) = 2.59 $km^2$ = 640 acres

1 million gallons per day (mgd) = $1.12 \times 10^3$ af/yr = 694 gpm

1 billion gallons per day (bgd) = 1550 cf = 3.785 million cubic meters/day

1 inch = 25.4 millimeters (mm)

1 mile = 1.61 kilometers (km)

1 acre-foot (af) = 4,356 cf = 325,851 gal = 1,233.5 cubic meters

1 cubic foot ($ft^3$) = 28.317 l = .028 $m^3$ = 7.48 gal = 62.4 lbs. of water

1 cubic yard ($yd^3$) = 0.765 $m^3$

1 U.S. gallon = 3.785 l.

1 pound = 0.453 kg.

1 metric ton = 1.1 ton

## Appendix D: Geographical Regions

The 17 Western and Great Plains States have been divided into eight regions roughly the same as those in Morris E. Austin's Land Resource Regions and Major Land Resource Areas of the United States. These regions (Figure D-1) overlap with the Great Plains, Mountain, and Pacific regional divisions and also with the ecoregions (Figure E-1); however, the overlaps are not exact. The location, topography and elevation, climate, geology, water, and population centers of each region are described here to give a general understanding of their diversity. (Austin, 1972)

### a. Northwest Rangeland

Location: This region runs north-south along the eastern edge of the Cascade Mountains with extending arms along the Columbia and Snake Rivers.

Topography and Elevation: This is an area of varied topography including mountain foothills, basins, plains, and plateaus. The elevation ranges from 1,000 feet on the plains, to about 4,500 feet on the plateaus, to 10,000 feet at the crests of some mountains.

Climate: The average annual precipitation is less than 20 inches, with an extreme low of 6 inches. Winter rainfall is greater than summer rainfall. Average annual temperatures range from 40°to 55°F. Average freeze-free periods range from 50 to 200 days.

Geology: The geology of this region is primarily volcanic rocks of Quaternary and Tertiary age. Soils vary widely, but the alluvials are frequently the most productive.

Water: Water from the Columbia and Snake Rivers irrigates agricultural areas.

Population Centers: Spokane, Washington (309,000 pop.) and Boise, Idaho (114,033) are the population centers of the region.

### b. California Subtropical

Location: This region lies within the State of California, covering the coastal plain and central valley regions west of the Sierra Nevada and the Southern California mountains.

Topography and Elevation: The coastal plain and central valley both range from sea level to 2,000 feet in elevation.

Climate: Average annual precipitation is from 5 to 25 inches with very dry summers. Freeze-free periods may be year-long in the southern portion of the region and near the coast, and are generally 250 days long elsewhere. Average annual temperatures are from 55° to 65°F.

Geology: The valleys are alluvium-filled; the coastal plain is geologically composed of granitic outcrops and marine depositional material.

Water: The Sacramento and San Joaquin Valleys are heavily irrigated from the Sacramento and San Joaquin Rivers and from groundwater sources.

Population Centers: A favorable climate and heavy industrialization have led to a high-density population, and urbanization continues to expand rapidly, often crowding out agriculturally productive land. Population centers are Sacramento (90,000), San Francisco (3,158,000), Fresno (464,000), Los Angeles (6,997,000), and San Diego (1,624,000), each with a large suburban area.

c. Western Plains and Plateau Rangeland

Location: This is the largest of the regions, extending from south and west of the Cascades and Rockies, south to the Mexican border, and east into the Trans-Pecos area of Texas. Much of this area is public land.

Topography and Elevation: The region is a basin and range type of topography with plateaus varying in elevation from about 4,500 to 7,500 feet, and basins as low as 250 feet below sea level in the Imperial Valley. There are a few small mountain ranges with peaks as high as 13,000 feet. The lower Colorado River valley provides the only large expanse of low-lying land.

Climate: The average annual precipitation is generally less than 10 inches on the plains, but may be as high as 40 to 50 inches in the mountains. Precipitation is higher in the summer in the southeastern portion of the region. Elsewhere, rainfall tends to be higher in winter. Average annual temperatures are 45° to 55°F, ranging from 35° in the north to 70° in the south. Freeze-free periods range from less than 90 days in the north to more than 240 days in the south.

Geology: The region has a great variety of geologic formations. The geologic origin ranges from volcanic to terrestrial and marine depositions, and the ages of the rock extend back to the Precambrian Age. The Colorado Plateau at the Four Corners area (common border point of Arizona, New Mexico, Colorado, and Utah) where the Grand Canyon cuts through and reveals the many layers of sedimentary rock is the outstanding geologic feature.

Water: All principal rivers in this region have their headwaters in the mountainous area, flowing into and through dry areas. They are the Colorado, the Humboldt and the Rio Grande Rivers.

Population Centers: The region is sparsely populated but has urban centers at Salt Lake City, Utah (800,000); Las Vegas, Nevada (346,000); Phoenix (1,224,000) and Tucson (451,000), Arizona; Albuquerque, New Mexico (393,000); and El Paso, Texas (431,000).

### d. Rocky Mountain Rangeland

Location: The Rocky Mountain chain extends into the U. S. from Canada and continues into New Mexico.

Topography and Elevation: The variances of topography and elevation are extreme, with valleys down to 2,000 feet and peaks up to 14,500 feet. The meadows are at about 8,000 feet.

Climate: In many valleys, average annual precipitation is less than 10 inches; average annual temperatures are 40° to 50°F. The longest freeze-free period is 120 days. The mountains receive more rain and snowfall, especially in the winter, but have lower average temperatures and a considerably shorter freeze-free period.

Geology: The region is heavily folded and faulted volcanic, sedimentary, and metamorphic rock. Alluvial soils are predominant in the valleys.

Water: Perennial streams fed by mountain rainfall and melting snow provide some of the area with sufficient water. The valleys and meadows of this region are prone to desertification processes because of slope drainage and water supply problems. This is especially true in the San Luis Valley of Colorado. Salinity problems result from heavy irrigation.

Population Centers: The ruggedness of the terrain has forced settlement into the valleys, where the most agriculturally-productive lands are, creating an increasing conflict between the needs of urbanization and agriculture for both land and water. The area is sparsely populated, with the largest population and industrial center at Denver, Colorado (1,438,000), and with other smaller populations centers spread along the Front Range.

### e. Northern Great Plains

Location: This region extends along the Canadian border, encompasses the northern portion of Montana and the entire State of North Dakota, and extends though the central portion of South Dakota.

Topography and Elevation: The region is comprised of smooth, rolling plains on which spring wheat thrives if enough moisture is available. Elevations range from 1,000 to 4,000 feet.

Climate: Average annual precipitation ranges from 10 to 24 inches and most of it occurs during the growing season. Average annual temperatures are 40° to 45°F. The freeze-free season ranges from 100 to 145 days.

Geology: Like most of the Great Plains area, the region is underlain by Precambrian basement rock and covered by sedimentary rock. Large areas of glacial deposition provided the parent material for the rich fertile soils which are predominant.

Water: The Missouri River system flows through this region, but most of the agriculture is dryland farming with irrigation from the river only in floodplain and adjacent areas.

Population Centers: The population density of the region is low. Bismarck (42,113), Grand Forks (42,052), and Fargo (58,256), North Dakota; and Pierre (12,110), South Dakota, are the main urban centers.

### f. Western Great Plains Rangeland

Location: This region has a north-south alignment and stretches from western Montana through eastern Wyoming, western South Dakota, into north-central Nebraska along the Platte River, eastern Colorado, and east-central New Mexico. It is comprised of the high plains and foothill regions just east of the Rocky Mountains.

Topography and Elevation: Elevation on these dissected plains and foothills ranges from 2,000 to 7,000 feet, with an average of 4,000 feet.

Climate: Average annual precipitation is 10 to 25 inches, and is spread over the months from mid-spring to autumn. Temperatures average 45°F, but are colder in the north and warmer in the south.

Geology: The region is Precambrian covered by sedimentary rock composition, as is most of the Great Plains. Reddish-brown soils cover much of the region.

Water: The Platte River system flows through the region, but little is used for irrigation. Dryland farming is prevalent, as is rangeland grazing.

Population Centers: Rapid City, South Dakota (53,070); Casper, Wyoming (46,903), and Roswell, New Mexico (39,511) are the main urban sites.

### g. Central Great Plains

Location: This region extends from southern Nebraska through western and central Kansas, western Oklahoma, and the Texas panhandle and rolling plains areas. The land is used primarily for rangeland and winter wheat production.

Topography and Elevation: This is a region of hills and rolling plains, ranging from 1,000 to 5,000 feet in elevation.

Climate: 15 to 30 inches of precipitation fall annually on this region, mostly during the summer months. Average annual temperatures range from 50° to 65°F, and the freeze-free period ranges from 150 to 240 days.

Geology: The geology of the region is cenozoic sedimentary rock several hundred feet thick overlying the Mesozoic Era rock. Soils typical of the prairies are prevalent.

Water: The Red and Arkansas Rivers flow through the region and provide irrigation water for adjacent land, but groundwater is the main supply for irrigation (Ogallala Aquifer). Center pivot systems are prevalent in the region.

Population Centers: The sparsely-populated region has urban centers at Lincoln, Nebraska (166,311); Wichita, Kansas (391,000); Oklahoma City, Oklahoma (762,000); and Lubbock, Texas (200,000).

### h. Southwest Plateau and Rangeland

Location: This small region lies within southwestern Texas.

Topography and Elevation: The plains and plateaus of this region range in elevation from sea level to 4,000 feet.

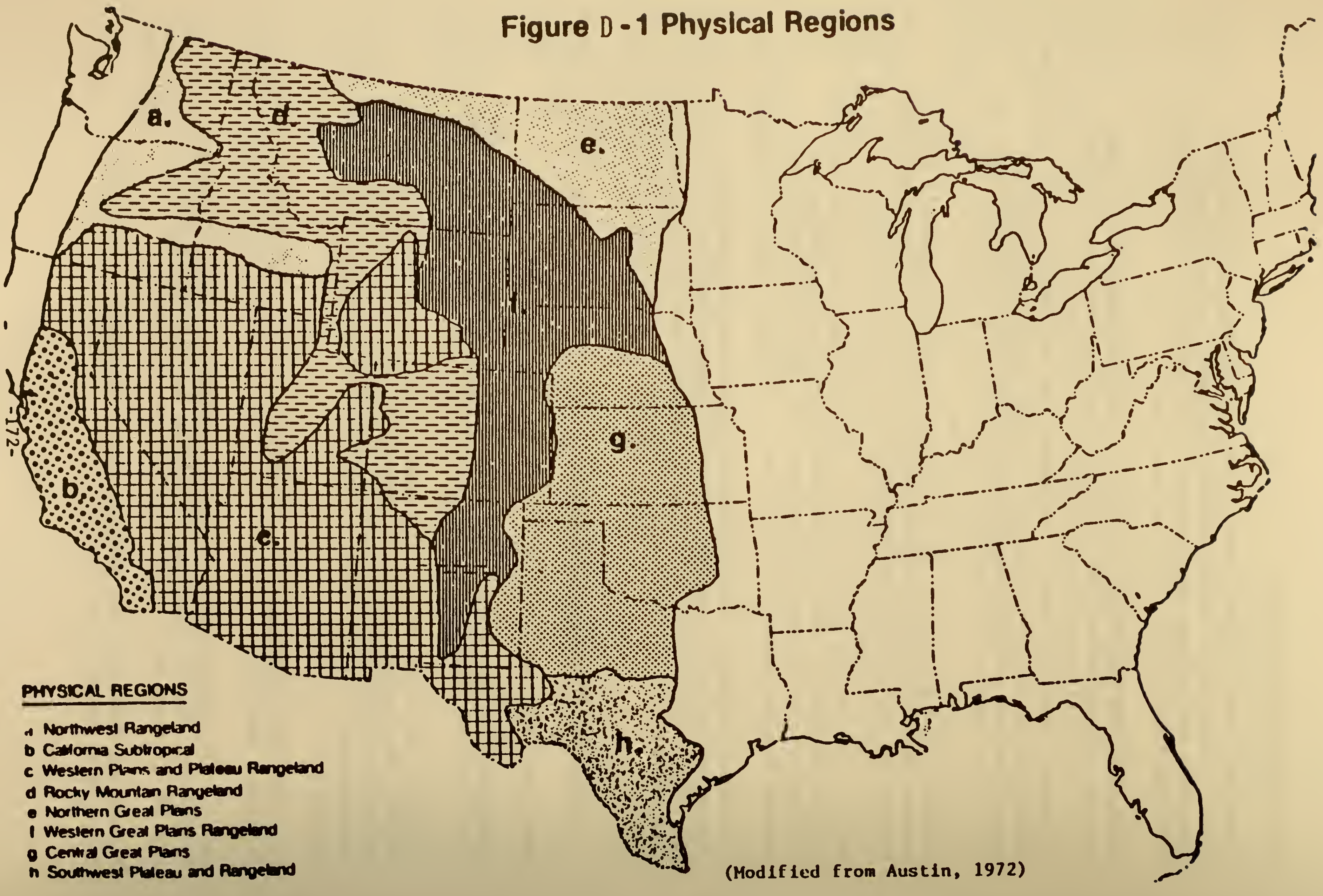
Climate: Although the average annual precipitation is 20 to 30 inches, the average annual temperature is high (60° to 70°F), making the effectiveness of the precipitation low due to high evaporation. Precipitation is divided seasonally between the spring and the autumn.

Geology: Sedimentary layers, primarily limestone, are found over Paleozoic Age rock.

Water: The Rio Grande provides some irrigation water within its floodplain, but the aquifers underlying much of the region provide groundwater for livestock and domestic needs.

Population Centers: San Antonio, Texas (996,000) is the main population center of the region.

Figure D-1 Physical Regions


a.
d.
e.
b.
c.
g.
h.
PHYSICAL REGIONS
a Northwest Rangeland
b California Subtropical
c Western Plains and Plateau Rangeland
d Rocky Mountain Rangeland
e Northern Great Plains
f Western Great Plains Rangeland
g Central Great Plains
h Southwest Plateau and Rangeland

(Modified from Austin, 1972)

# Appendix E: Ecological Regions

## Introduction

Desertification affects the biological as well as nonbiological components of an ecosystem because the conditions of soil, water, flora, and fauna have a direct effect on one another. To better understand the impact of the desertification processes, a general description of the ecoregions of the arid domain is presented in this chapter. The ecoregions presented here (Figure E-1) are simplified versions of those presented in Robert G. Bailey's book Description of the Ecoregions of the United States. In general, the regions overlap with the Great Plains, Mountain, and Pacific regional divisions and also with the geographical regions (Figure D-1); however, the overlaps are not exact. There has been no attempt to separate and indicate either pristine or present conditions, although some land is in nearly pristine condition with minimal disturbance, while other land is almost completely altered by human modification.

## Ecoregions

### a. Northwest Grassland Ecoregion

Vegetation: This ecoregion was once dominated by grasses, but now large areas are cultivated for wheat production. Most of the remainder of the region is vegetated by sagebrush, which has proliferated because of heavy grazing of more palatable plants by both domestic and wild animals.

Fauna: Wild animals which can inhabit the sagebrush cover include pronghorn antelope, deer, bobcats, coyotes, and species of birds and reptiles suited to shrub vegetation existence. The grazing wildlife are often in competition with the domestic animals for available forage.

### b. California Ecoregion

Vegetation: The vegetation of this ecoregion is very distinct because of the extreme seasonality of precipitation between the wet winter and the dry summer. The vegetation is predominately hardleaved evergreen trees and shrubs called sclerophyll woodland. The type is called sclerophyll because the leaves contain thick, hard walls in their cells to help prevent excessive mositure loss and wilting during the extremely dry and often hot summers. The other vegetation of this ecoregion was once predominately grassland, but it has been largely replaced in sections by fruit and vegetable crops and extensive acreage of grains. Large areas of shrubs such as creosote and chaparral exist in the southern part of the region.

Fauna: The larger wildlife mammal species such as the California grizzly, wolf, and the larger ungulates (hoofed mammals) have generally disappeared from the region due to urbanization and intensive agricultural use of the land. Large domestic livestock are prevalent, with California ranking seventh in the nation in both cattle and sheep production in 1977. Wild horse and burro populations are significant. Smaller wild mammals such as coyotes, rabbits, and rodents are able to live near the cities and in the woodlands. Several species of birds and reptiles are present in the region, but amphibians and fish can exist only at large perennial reservoirs because small reservoirs often evaporate completely during the hot, dry summers.

### c. Western Shrub and Brush Ecoregion

This large region is divided into smaller sections by the type and density of shrub and/or brush:

1. Great Basin
2. Colorado Plateau
3. Southwestern U. S. Desert
4. Chihuahuan Desert
5. Wyoming Basin

#### (1) Great Basin

Vegetation: The Great Basin section of this ecoregion is dominated by sagebrush and other shrubs, such as shadscale, fourwing saltbrush, and greasewood, which have the salt tolerance necessary to withstand the salinization of soil produced by the drainage to interior basins. On the slopes of the hills and mountains of this section, the vegetation may be vastly different due to lower salinity, summer temperatures, and greater precipitation.

Fauna: Scarcity of potable water and desirable forage makes large wild species of mammals such as deer sparse. Jackrabbits, kangaroo mice, snakes, and hawks, which are adapted to dry environments, are relatively plentiful. Much of this area is federally owned and livestock grazing permits are issued. Wild horses and burros also graze in the area.

#### (2) Colorado Plateau

Vegetation: In the lower altitudes of the Colorado Plateau section, vegetation types include cactus and yucca, sparse grasses, and sagebrush. Higher altitudes of this dry plateau are chiefly covered by pinyon and juniper woodlands while pine and spruce forests are prevalent in the higher, more moist locations. Highly variable and erratic precipitation makes dry farming impractical, as unreliable water resources for irrigation hamper large cropping efforts. Therefore, most of the land is used for livestock grazing.

Fauna: Because of the proximity of the mountain forests and woodlands, larger wild animals such as elk and pronghorn can be found in this region, though they seldom range deeply into the arid lowlands. Animals such as jackrabbits and rattlesnakes which are adapted to arid lands live in the lower altitudes. Domestic cattle and sheep graze the short grasses and some of the brush species.

(3) Southwestern U. S. Desert

Vegetation: In this section encompassing the U. S. portions of the Mojave, Colorado, and Sonoran Deserts, there is only sparse vegetation, and bare ground is conspicuous. Cacti and shrubs such as creosote and mesquite predominate. Upland areas may contain plants such as Joshua tree and juniper. There is livestock grazing in some areas, but the shortage of water precludes most agricultural endeavors.

Fauna: Many species of desert birds and reptiles live in this section, but there are very few large animals of any type. Most wild animals are small nocturnal burrowers who avoid the heat of the desert day.

(4) Chihuahuan Desert

Vegetation: In the U. S. portion of the Chihuahuan Desert thorny shrubs are the dominant vegetation. Short forage grasses are found in association with the shrubs, but this region has a low carrying capacity. Mesquite, creosote, and ocotillo are commonly found. Phreatophytes, such as mesquite, tap the water table with their deep root systems but waste water through rapid transpiration.

Fauna: In addition to the small desert animals found in the Southwestern U. S. desert, larger animals such as deer, antelope and javelina are found in the ripatian vegetation of the intermittent streams in the Chihuahuan Desert section of the Western Shrub and Brush Ecoregion. A limited number of domestic livestock are grazed here.

(5) Wyoming Basin

Vegetation: The vegetation of this basin is a mixture of short grasses and shrubs such as sagebrush, shadscale, or alkali-tolerant greasewood. Some wheat is dry-farmed, and some feed crops are irrigated. There is limited livestock production.

Fauna: Wildlife flourishes in this sparsely populated and largely undeveloped section. The low carrying capacity of the land, however, intensifies the competition for available forage between wildlife and domestic livestock. Coyotes, antelope, and the large cats such as the mountain lion and bobcat are the primary larger species of wild animals, and the smaller species include ground squirrels, rabbits, and rodents. Migratory animals use this basin for breeding, feeding, and resting during their travels. Migratory waterfowl are common here.

### d. Rocky Mountain Ecoregion

Vegetation: In the Rockies, altitude effects the amount of precipitation, temperature, and prevailing winds, thereby creating belts or zones of different vegetation. The highest zone is above the "timber line" and has the short grasses and sedges characteristic of tundra vegetation. The next lower zone is one of forests of spruce and fir trees. The forests of the next lower area are of pine and fir trees. Next is a zone of shrub woodlands dominated by pinyon and juniper. Finally, in the dry valleys and plains beyond the mountain foothills are the arid sections of grasses, shrubs, and cacti. Few crops are cultivated here, with grazing being the principal agricultural occupation.

Fauna: Large wild animals are common in this altitudinal zone's vegetation. Bears, elk, and mountain lions are representative of the large mammal wildlife, while squirrels, chipmunks, and rodents are representative of the smaller species. Domestic livestock are grazed on the forage grasses of the middle vegetation zones. Many varieties of birds, reptiles, amphibians, and fish inhabit one or more of the vegetative zones of the Rocky Mountains.

### e. Great Plains Steppe Ecoregion

Vegetation: The ecoregions discussed here and the physical regions discussed in the geographical data section do not exactly coincide. The western Great Plains, while divided mainly by topography into three physical regions-the Western Great Plains Rangeland-was once almost completely covered by short grasses. The common name of typical grass of the area, buffalo grass, suggests the historical importance of this mammal in the region. Though grasses predominate, they do not cover all the land, and bare spots are common. While the greater part of this region is used for grazing, there is extensive acreage in dry-farmed wheat and some irrigated feed crops along the streams.

Fauna: Wild animals such as deer, antelope, rabbits, and prairie dogs are plentiful throughout the section, and are preyed upon by coyotes and other predators. Birds such as grouse are common, and the livestock grazing development of the area has led to stock ponds useful to migratory waterfowl.

### f. Great Plains Prairie Ecoregion

Vegetation: In contrast to the short grass ecoregion described above, this ecoregion is dominated by mid- and tall grasses such as (mid- and tall) big bluestem, switch grass, and indiangrass; porcupine grass, little bluestem, and western wheatgrass. The boundary which separates the mid- and tall grasses from the short grasses is indistinct and constantly changing with the precipitation variations of the region (McGinnies, no date). There are some areas of mixed short and tall grasses, but large vegetation such as trees is sparse throughout the region.

Wheat production dominates the agricultural output, with other grains such as sorghum being of some importance in the southern part of the region. Irrigation from ground water sources is used for local fruit, vegetable, and cotton production. Grazing is still an important agricultural activity, but feedlot cattle production is increasing.

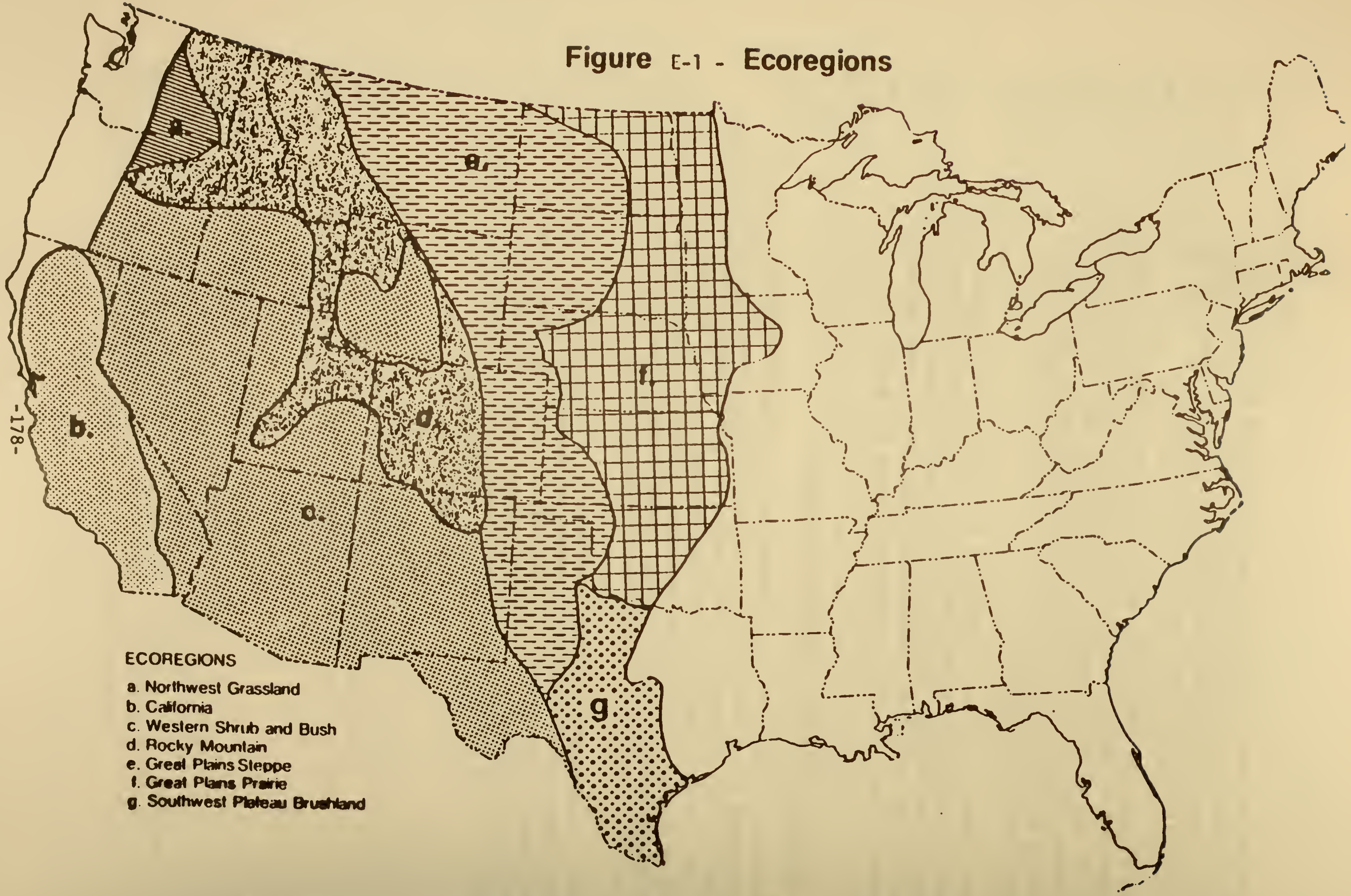
Fauna: The ecoregion is populated by a variety of mammals which range in size from domestic cattle and antelope through sheep, coyotes, and badgers to the small rodents and rabbits. Birds and reptiles are plentiful, as are amphibians and fishes which are abundant in and near the steams that cross the area.

### g. Southwest Plateau Brushland Ecoregion

Vegetation: This area is characterized by grasses mixed with shrubs. The grasses are predominately bluestem, buffalo grass, and grama; the shrubs are mainly mesquite and juniper, and oak species such as live oak are found. Grazing is the dominant agricultural activity, but crops such as cotton, wheat, and other grains are grown where conditions permit. The lower Rio Grande Valley is warm and moist enough to provide for citrus fruit and winter vegetables.

Fauna: Livestock are predominant in this area, with much of the sheep production of the United States located here. Angora goats are also prevalent here, and virtually all of the U. S. production of mohair is in this area. Wildlife such as deer, wild turkeys, armadillo, and quail, as well as several reptile species, are abundant.

# Figure E-1 - Ecoregions



After Robert G. Bailey, Description of the Ecoregions of the United States, USDA, Forest Service, 1978.

# Appendix F: Climatological Conditions of Arid and Semiarid Lands

## Introduction

The main characteristic of arid and semiarid lands is a low average precipitation or moisture, a condition which is directly affected by other variable elements of the climate, such as temperature, sunshine, wind and moisture conditions (figures F-1, F-2). Two climatological extremes common to the study area--drought and flash floods--are discussed in this Appendix.

The Appendix also briefly examines the effects of albedo and climate change and their known and potential impact on desertification.

## 1. Drought

Drought is an important and predominant climatological feature of arid and semiarid areas, and it affects local and regional residents physically and economically. Drought is a normal temporary event which occurs in varying patterns and frequency throughout the U. S., one which may trigger or intensify desertification where unsound use of the resource base is prevalent.

It is important to distinguish between aridity and drought. Aridity is a permanent climatic condition of low average precipitation. Drought is a temporary phenomenon in which precipitation is significantly lower than average (Rosenberg, 1978). The length of one drought event can range from a few months to several years.

Drought is pervasive in nature, and it is often difficult to ascertain when a drought begins. Unlike other natural hazards, the losses characteristically do not include structural damage or direct loss of life, even though many famines have been direct results of droughts.

Droughts involve great uncertainty in terms of where and when they will occur, duration, severity, and extent of impacts. The severity of this type of event is measured in terms of:

--Actual precipitation in comparison to the average annual precipitation
--Duration
--Season of episode
--Frequency (Heath, 1978).

Drought is related to anomalous occurrences in the atmospheric circulation and solar phenomena. Yet, there is no agreement among meteorologists on how these abnormal circulation patterns are generated.

Because we cannot currently predict the incidence or severity of drought, it is advisable for localities where drought frequency is higher to have alternative resource management plans prepared so as to ameliorate short-

and long-term impacts (WESTPO, 1978). Some responses to two historical droughts are presented in figure F-3.

## 2. Flash Floods

Flash floods are produced by highly localized and abundant rainfall caused by occasional slow-moving weather fronts; orographic lifting and thus cooling of warm, moist air; and "Mexican hurricanes" or tropical low-pressure centers which move from the Pacific onshore in Mexico and then northerly or northeasterly into the arid and semiarid regions of the U.S. Flash floods also occur due to physiographic conditions such as watershed relief, drainage, geology, topography, the existing vegetation, and hydrologic conditions.

Rainfalls of 3.5 inches in 1 hour are not unusual in the Western States (Renard, et al., 1970). There are reports of 1.17 inches in 3 minutes (Bigger, 1959), and even of 7 inches in 30 minutes (Hoyt and Langbein, 1955). While the more intense rainfall usually comes at the beginning of the storm, it may be followed by an hour of more or less intense rainfall, producing a great deal of runoff. In one flash flood in Arizona, streams rose 5 to 10 feet per hour, and one creek crested at 36 feet over the normal level (NOAA, 1971).

Flash floods do considerable damage to property, soil, plants, animals, and people. Severe erosion, silt, and sediment in waterways are the immediate manifestations of flash floods, but the loss of flora, fauna, and nutrients is of great import as well.

## 3. Albedo

Albedo is the portion of incoming solar radiation which is reflected back into the atmosphere. Light-colored objects (e.g., clouds) reflect back more radiation and thus have more albedo. Because the arid areas have characteristically clear skies, they have a low atmospheric albedo. Much of the incoming solar radiation reaches the surface and is absorbed by the land which, in turn, raises the surface and soil temperature.

On the other hand, the amount and distribution of the vegetation covering the soil affects the albedo of the land. Dry, bare lands have a higher surface albedo than do humid, densely vegetated lands because more solar radiation is reflected by the ground. An increase in surface albedo may unfavorably alter the water budget of an area, causing the soil to further degrade, with desertification as a possible result. Indiscriminate use of fire, overgrazing, deforestation for slash-and-burn agriculture or for fuel and timber, and salinization of soils are some of the activities that result in the destruction of vegetation and the creation of salt flats, producing higher albedo rates than the area had originally (Sagan, Toon, and Pollack, 1979). It has been suggested that higher surface albedo may affect the microclimate of the affected region as well.

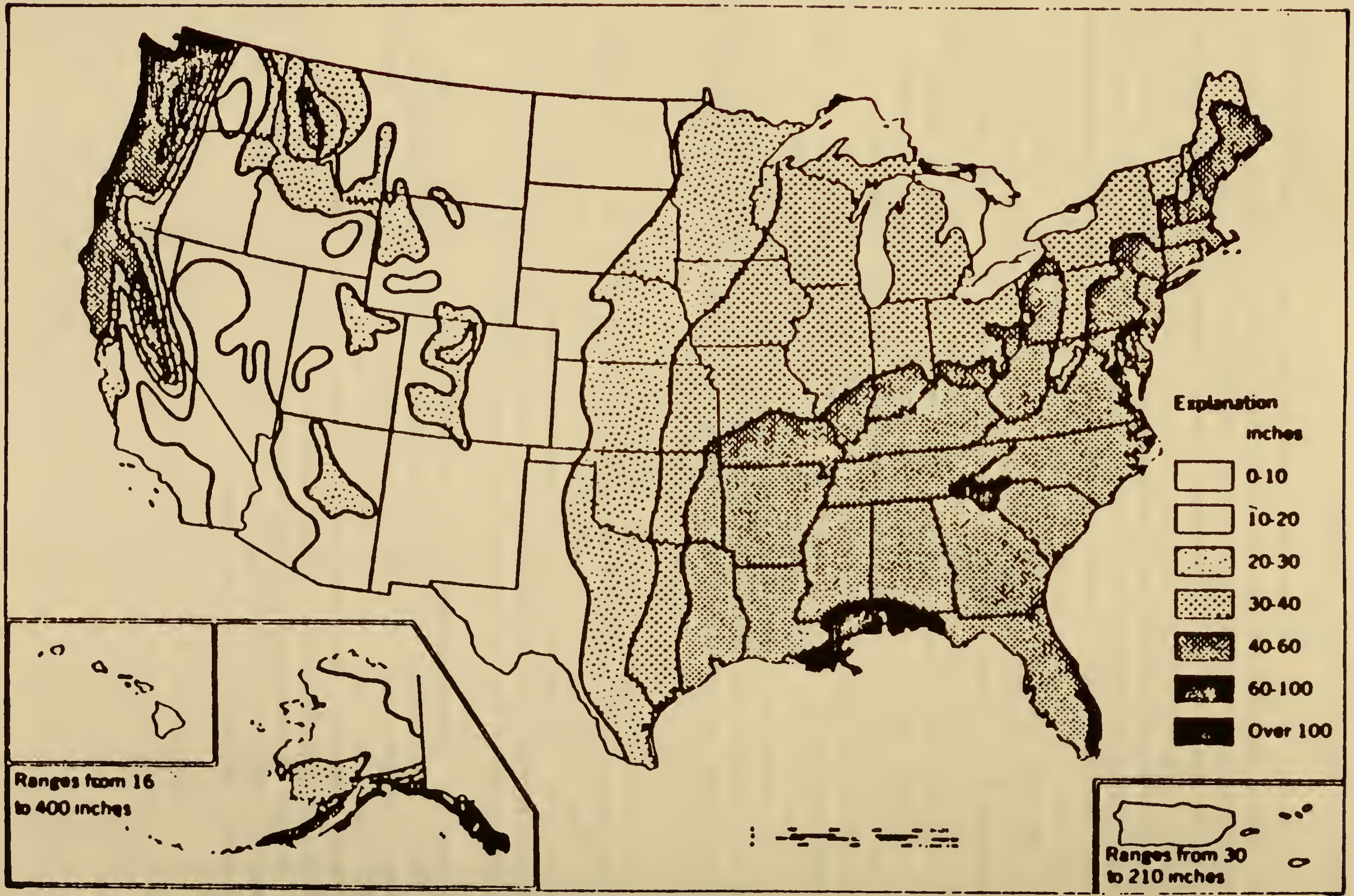
## 4. Climate Variability and Changes

Climate is highly variable over all time scales, and the meaning of climatic change depends on the defining period for the climate average. For example, during the past billion years the prevalent condition of macroscale climate was one of relative warmth (as much as 10°C warmer than at present). However, this condition was punctuated by at least three major ice ages, each one about 10 million years long. Roughly 50 million years ago a gradual cooling appears to have started culminating with the Quaternary Ice Age about 2 million years ago. On another time scale, and during the last 10 to 12 thousand years, cool and warm cycles have occurred as well, such as the advance of ice masses about 10,800 years before the present, and the postglacial warming culminating between 5000 and 4000 B.C. More cooling and warming cycles have occurred since, lasting one to two millenia each. On an even shorter time scale, climatic records register 150-200-year cycles of warming and cooling, with the "Little Optimum" epoch during A.D. 1150-1300 and the "Little Ice Age" during the 1550-1700 A.D. period as examples. Though in the last thousand years the global temperature has fluctuated on the order of 1.5°C, and changes in climate are constantly occurring, this is the first time in history that humankind has the power to upset the climate, or at least to hasten the rate of change (NAS, 1979). For example, the burning of fossil fuels and the changes in natural vegetation distribution and amounts have led to steadily increasing atmospheric concentrations of carbon dioxide ($CO_2$).

Recent studies have shown that the continuation of this trend will lead to double the amount of $CO_2$ in the atmosphere by the first half of the 21st century. This condition could result in the warming of the earth's surface between 2°C and 3.5°C, with greater increases at higher latitudes. The uncertainty of the estimate is due to the imperfect ability to predict the future behavior of both human and biospheric activity.

The increase in temperatures could have a strong effect on the climate, due to shifts in the distribution of climatic regimes. It is probable that these changes could be delayed by the capacity of the deeper oceans to absorb heat, but when equilibrium is reached, warming will occur (NAS, 1979). In turn, any changes in climate will have many impacts along a chain of reactions, from changes in crop production to the effects on farm or pastoral management, the external markets, and the supplies of energy, fertilizer, and fisheries (Hare, 1980). Of course, conditions of the resource base will also be altered.

Figure F-1



**Average annual precipitation.**

Source: U.S. Water Resources Council, The Nation's Water Resources, 1978.

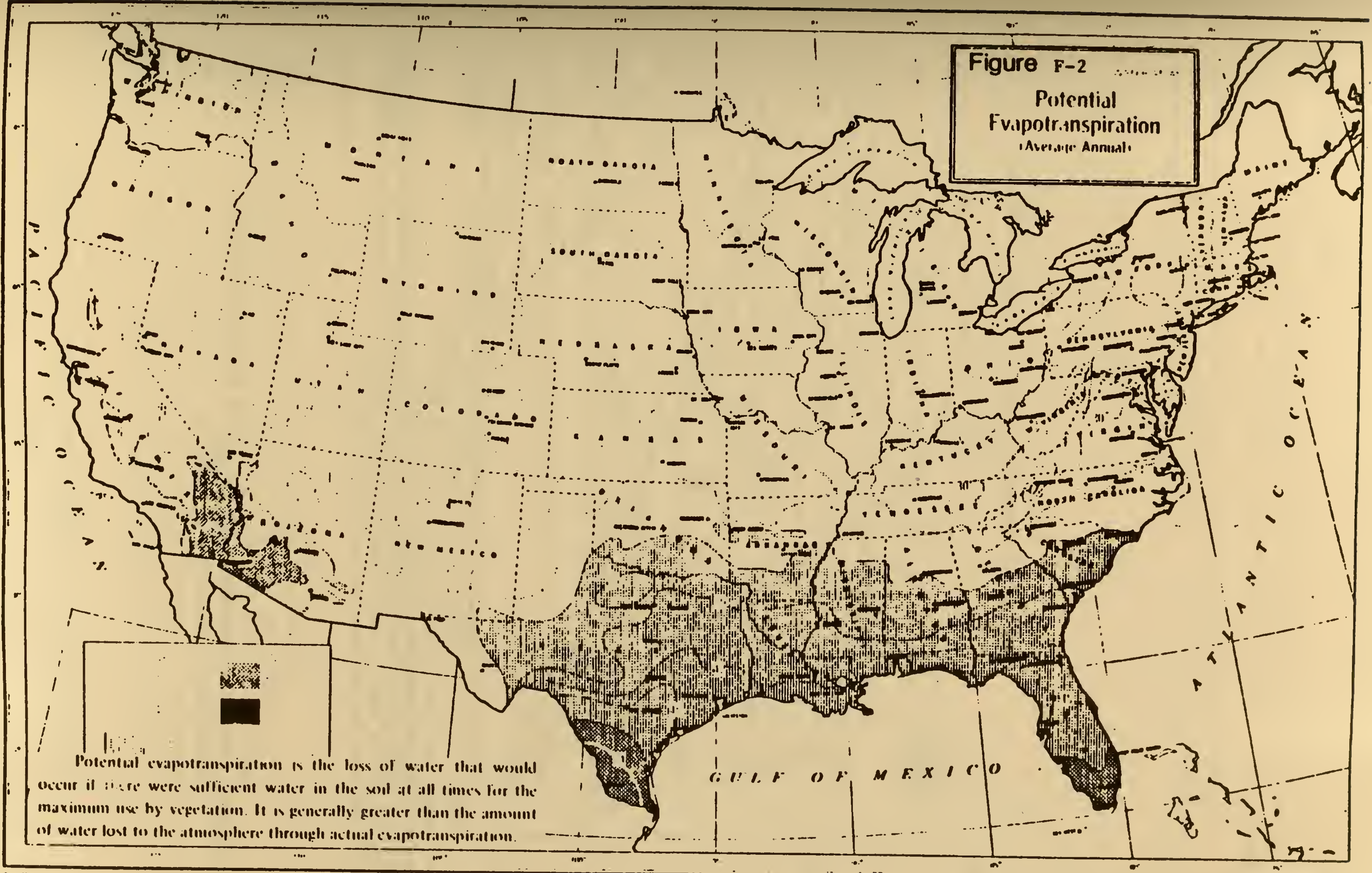


Figure F-2

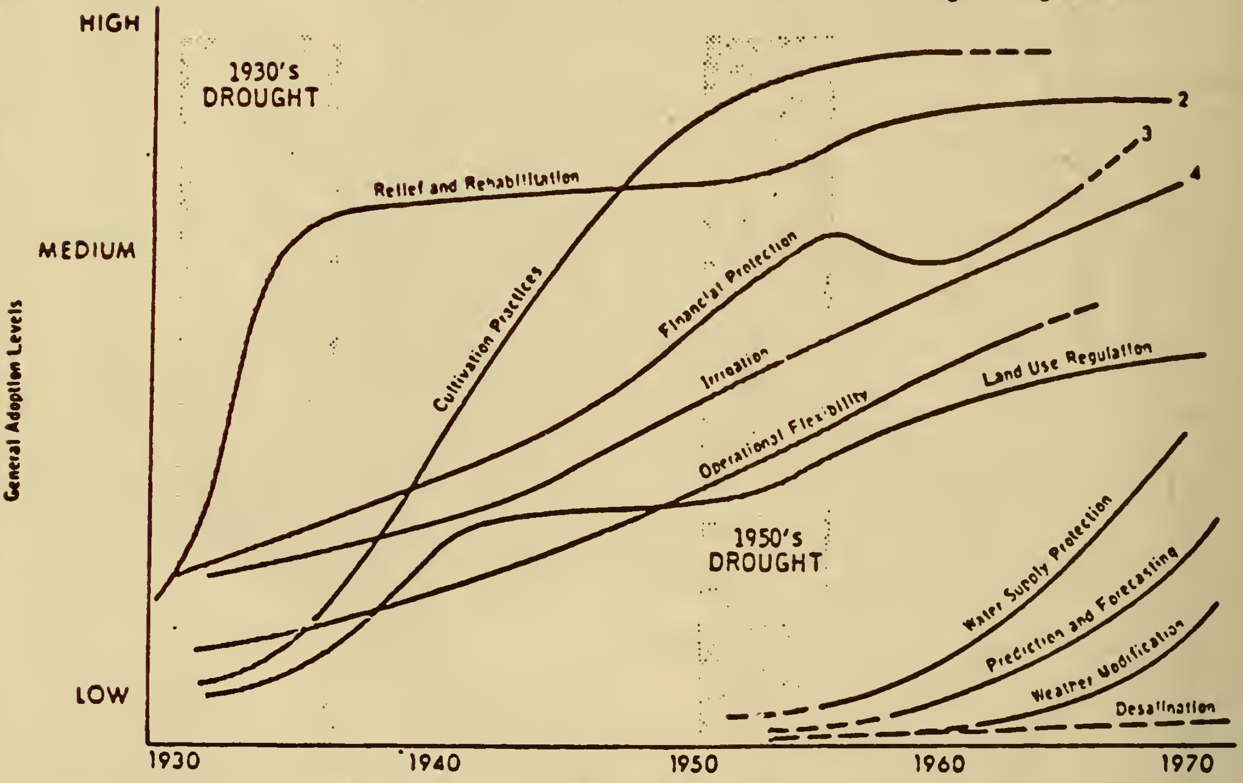
Potential Evapotranspiration (Average Annual)

Potential evapotranspiration is the loss of water that would occur if there were sufficient water in the soil at all times for the maximum use by vegetation. It is generally greater than the amount of water lost to the atmosphere through actual evapotranspiration.

Source: James L. Geraghty, et al., Water Atlas of the U.S., Port Washington, N.Y.: Water Information Center Publication, 1973.

Figure F-3

Generalized Historical Trends of Drought Adjustment



1. Very rough approximation of relative levels of adoption
2. Institutional arrangements for R&R -- not payments
3. Shape of curve generalized from number of acres insured and amounts of loans in the United States (dip in 1950's reflects lower adoption of insurance at that time)
4. Based on total irrigated acres in the United States

Source: Norman J. Rosenberg, ed., North American Droughts,
Boulder, Colorado: AAAS, 1978.

## Appendix G: Soil

The soils of arid and semiarid lands have characteristics which make them prone to erosion, waterlogging, and/or salinization.

Soil is the mineral and biologically active portion of the earth's surface which supports vegetative growth. Some of the characteristics that determine the types of soils are:

- content of sand, clay, and silt
- acidity or alkalinity
- depth
- porosity
- permeability
- color
- organic matter content; and
- temperature.

Soils of the arid regions of the United States belong principally to the Aridisol, Mollisol, Entisol, Alfisol, Vertisol, and Ultisol soil orders (Dregne, 1976). Upland soils are usually medium-to-coarse textured; soils of topographic depressions and along the coastal plains of Texas are fine-textured; and soils found on river flood plains are of variable textures. Most of the soils have slightly acid to alkaline reactions (pH) and are calcareous at depths of less than 6 feet (2 meters). Organic matter contents are low, and soil structure is weakly developed.

The USGS National Atlas of 1970 defines the cited orders of soil as follows:

Alfisols: soils with gray to brown surface horizon, medium to high base supply, and subsurface horizons of clay accumulation.

Aridisols: soils with pedogenic horizons, low in organic matter, usually dry.

Entisols: soils with nearly black, organic-rich surface horizon and high base supply. Exceptions are the Psamments.

Ultisols: soils with horizons of clay accumulation and low base supply.

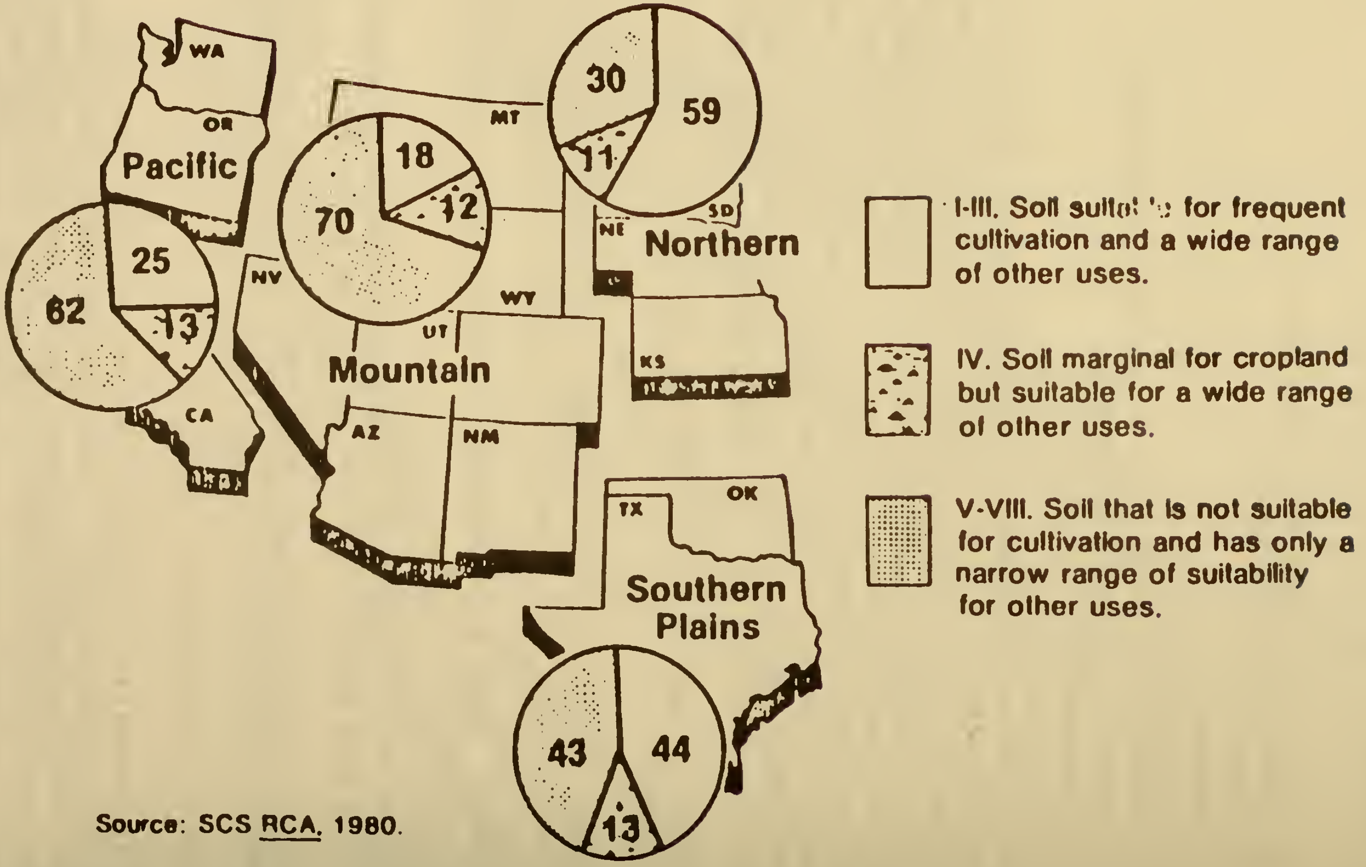
Vertisols: cracking clay soils.

Soil is classified by agricultural suitability into land capability classes I-VIII, which are defined in the glossary. Higher numerals indicate greater limitations and narrower choices for agricultural use. Figure G-1 shows the relatively small amount of privately-owned land suitable for cultivation in the 17 Western States. Comparable data for federally-owned land is not available; however, it is generally acknowledged that a larger proportion of federal land is in classes IV through VIII.

It is a BLM goal to have soil surveys for federal lands completed by 1989. The USDA is assessing land capability classification of these same lands.

Figure G-1

## Percentages of soil in capability classes I-VIII, by farm production region.


WA
OR
Pacific
25
13
62
CA
NV
MT
18
12
70
WY
UT
Mountain
AZ
NM
30
59
11
SD
NE
Northern
KS
TX
OK
Southern Plains
43
44
13
☐ I-III. Soil suitable for frequent cultivation and a wide range of other uses.
▨ IV. Soil marginal for cropland but suitable for a wide range of other uses.
▒ V-VIII. Soil that is not suitable for cultivation and has only a narrow range of suitability for other uses.

Source: SCS RCA, 1980.

# Appendix H: Water

## Introduction

The main characteristic of the hydrology of arid and semiarid regions is the scarcity of the water circulating through the system. Since evaporation exceeds precipitation, an imbalance between supply and demand results when developmental, agricultural, or other activities are attempted. To compensate for these differences, large waterworks to impound and transfer surface waters have been built, and groundwater, the other basic and sometimes unique supply, has been tapped through the years. In some cases, withdrawals exceed recharges, resulting in the sustained mining of the resource. Conflicts have emerged, and will emerge from, the old and new water uses and users. To resolve them, economic and social values must be considered in addition to physical, technical, and legal constraints.

## Input to the System

### (1) Surface Water

Input into the hydrologic system is from precipitation in various forms which does not necessarily enter at the time or location of use. Rivers and other bodies of surface waters may have sources far from their course and be fed by precipitation outside the drylands. Runoff from precipitation in the arid regions also augments the flow of rivers, but rainfall is highly variable in time and area affected. The intensity of precipitation is usually the important factor in the runoff occurrence in arid and semiarid lands as the duration of precipitation is generally short. Topographic and geological factors such as degree of slope, soil and rock morphology, and other aspects also affect runoff. Snowmelt from mountains represents a large component of the runoff volume.

The principal rivers and major drainage basins of the Western U. S. which receive precipitation runoff and from which water is withdrawn to satisfy human needs are shown in figure H-1. Figure H-2 shows their water supply and use.

### (2) Groundwater

Groundwater is an important source of water supply in the Western States. It is estimated that there are approximately 6.2 million acre-feet of water in storage at depths of 50 to 200 feet in the 11 Western States (Bureau of Reclamation, 1975). It is estimated that there are more than 340 million acre-feet in the Ogallala Aquifer in the High Plains of Texas, from which between 8 and 9 million acre-feet are pumped each year for irrigation. Projections indicate that by the year 2030 available water will be about 2.2 million acre feet annually to irrigate less than one-third the acreage now in operation (Grubb, 1978). However, the amount recoverable is not known because of lack of needed information, e.g., location of supplies with respect to users, physical data in depth and nature of aquifer, pumping costs, groundwater quality, and policies on groundwater use.

Aquifers are recharged through infiltration of precipitation and runoff in aquifer outcrop areas. In some cases, the rainfall occurred over long periods and slowly accumulated in porous underground formations. Because this type of aquifer recharge is so slow, this resource should be treated as nonrenewable. Groundwater is being mined in several locations throughout the Great Plains and Western States (figures H-3, H-4, and H-5), and large declines in water levels in areas supplied by aquifer systems such as the Ogallala have been measured.

There are two types of aquifers: consolidated or rock aquifers, and unconsolidated aquifers. The main kinds of consolidated aquifers in the Western U. S. are sandstone, carbonate rock, a combination of both, and volcanic rock. The unconsolidated aquifers, which are extensive throughout the West, generally have specific yields ranging from 10 to 20 percent of volume but a wide range of permeabilities due to varying size and distribution of interstices between the grains. Beds of sand and gravel commonly yield a few hundred to a few thousands gallons per minute of water to wells. These may also be described as artesian (confined) or water-table (unconfined) systems.

Volcanic rocks, primarily basalt, occur mainly in the Northwest and generally have low specific yields, ranging from less than 1 percent to about 3 percent, depending on the width and distribution of fractures. Yields of a few hundred gallons per minute of water are common from wells in sedimentary rocks, especially limestone and dolomite. Consolidated sandstone contains excellent aquifers in parts of the Great Basin, the western Missouri River, and the Rio Grande regions. Yields of wells completed in limestone commonly range from a few hundred to a few thousand gallons per minute. The yields of wells completed in sandstone generally range from a few ten to a few hundred gallons per minute (gal/min). The yield of wells completed in shale generally is less than 10 gal/min. Crystalline rocks, widespread throughout the Rocky Mountains, generally yield less than 10 gal/min to wells, but they do provide adequate water for domestic supplies at many mountain homesites.

On the Great Plains, there is a large system of groundwater in unconsolidated sand and gravel aquifers. Most of the large-scale pumping for agricultural use occurs in this type of aquifer. In Nebraska alone, there are now more than 15,000 center-pivot irrigation systems, and their number is growing rapidly each year (Wilhite, 1979). Water use is estimated at 407,000 gallons per acre per year. There is also large concentrations of wells in the central California valley, in the Phoenix-Tucson area of Arizona, and on the Texas High Plains.

## Output from the System

Hydrological output from the system includes evaporation, transpiration, seepage and runoff.

Evaporation and evapotranspiration represent significant water losses from water surfaces, soil, and plants, which effectively reduce the amount of available water in an already water-deficient region. Plants transpire water by taking it from the soil through the root system and releasing humidity through their leaves. It has been calculated that crops under irrigation consume 41 percent of the gross diverted water by evapotranspiration. See figure H-6. Uncontrolled growth of certain plants, such as phreatophytes, which transpire large quantities of water can drastically reduce the water available for desirable plants.

The loss of water by seepage into the ground under rivers and reservoirs also is significant. Most of this water percolates to aquifer formations.

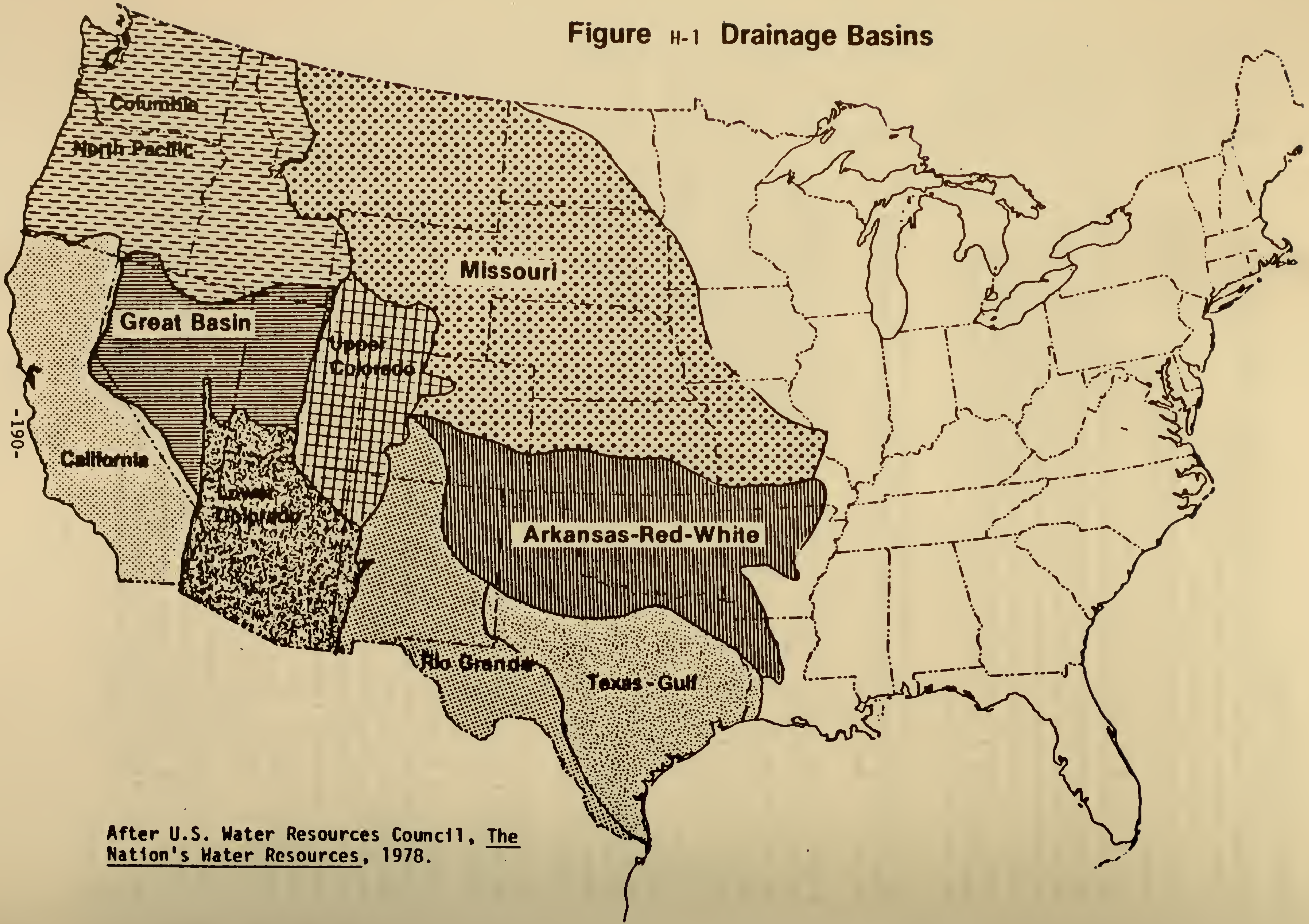
Runoff is the largest output from the system and may be defined as the precipitation that eventually flows into streams, either as surface runoff or as runoff from groundwater discharge. Rainfall that reaches the surface of the ground initially infiltrates the soil, but once the capacity of the surface to hold water is exceeded, water begins to flow across the ground in trickles or sheets under the influence of gravity. This is surface runoff. Surface runoff increases from small rivulets at the beginning of a rainstorm to a steady torrent if the rain lasts long enough to saturate the storage mechanisms in and on the soil. Toward the end of a prolonged rain, nearly all of the water that reaches the ground joins the surface runoff.

In contrast to the rapid variations of surface runoff in response to precipitation, groundwater runoff discharge provides a much steadier flow of water to streams (Muller, 1974).

Runoff from groundwater supplies the base flow that maintains rivers through periods of drought; however, base flow is rather insignificant in arid and semiarid lands (See figure H-7.) On the other hand, extreme use of groundwater resources may reduce the flow of streams and deplete surface water supplies. A recent court case in Nebraska favored a surface water user against irrigators who had drilled wells for their center-pivot systems (Upper Midwest Report, Jan.-Feb. 1981). Land use has a very important direct effect on the runoff and infiltration rates (figures H-8 and H-9).

The unpredictable, erratic intensity of rainfall in the dry Western States, sometimes in conjunction with unfavorable soil traits, may increase the runoff leaving the system, thus decreasing the available moisture needed for plant production. Figure H-10 shows the variability of flow of the Colorado River at Lee Ferry, Arizona, over a period of 78 years.

Figure H-1 Drainage Basins



After U.S. Water Resources Council, The Nation's Water Resources, 1978.

Figure H-2

## Water supply and use

| Water data | 1975 Average annual water data by region (expressed in mgd) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Missouri | Arkansas-White-Red | Texas-Gulf | Rio Grande | Upper & Lower Colorado | Great Basin | Pacific Northwest | California |
| Instream requirements | | | | | | | | |
| Fish & wildlife (IFA) 1/ | 33,988 | 46,169 | 22,917 | 2,287 | 6,064 | 3,389 4/ | 214,004 4/ | 32,607 4/ |
| Navigation | 25,840 | 2,730 | 0 | 0 | 0 | 0 | 0 | 0 |
| Treaties and compacts | 42 | 188 | 0 | 54 | 1,340 3/ | 0 | 0 | 0 |
| Flow requirements | 33,958 | 46,169 | 22,917 | 2,287 | 6,864 | 3,389 4/ | 214,004 4/ | 32,607 4/ |
| Offstream requirements | | | | | | | | |
| Irrigation | 14,214 | 7,048 | 9,347 | 3,886 | 6,220 | 3,225 | 11,026 | 24,282 |
| Livestock | 450 | 215 | 180 | 38 | 74 | 33 | 72 | 98 |
| Steam-electric | 68 | 89 | 99 | 18 | 102 | 3 | 13 | 25 |
| Manufacturing | 136 | 165 | 571 | 6 | 57 | 24 | 329 | 257 |
| Domestic | 262 | 279 | 413 | 139 | 224 | 131 | 210 | 1,279 |
| Commercial | 69 | 69 | 94 | 29 | 38 | 16 | 55 | 155 |
| Minerals | 111 | 173 | 555 | 103 | 198 | 28 | 18 | 183 |
| Other | 159 | 26 | <1 | 22 | 122 | 319 | 190 | 362 |
| Consumptive requirements | 15,469 | 8,064 | 11,259 | 4,240 | 7,035 | 3,779 | 11,913 | 26,641 |
| Exports | 0 | 0 | 0 | 0 | 5,268 | 0 | 0 | 0 |
| Evaporation | 4,924 | 2,615 | 1,705 | 730 | 1,913 | 327 | 2,014 | 669 |
| Total water depletions | 20,393 | 10,679 | 12,964 | 4,970 | 14,216 | 4,106 | 13,927 | 27,310 |
| Replenishable supply | 61,525 | 67,694 | 35,626 | 5,309 | 13,351 | 5,976 | 268,523 | 68,050 |
| Surface water 2/ | 53,675 | 64,305 | 33,982 | 3,631 | 10,632 | 5,143 | 261,802 | 51,087 |
| Ground water pumped | 7,850 | 3,389 | 1,644 | 1,678 | 2,719 | 833 | 6,721 | 16,963 |
| Ground water mining | 2,557 | 5,457 | 5,578 | 657 | 2,415 | 591 | 627 | 2,197 |
| Imports | 411 | 128 | 30 | 234 | 0 | 101 | 47 | 4,438 |
| Total water supply | 64,493 | 73,279 | 41,234 | 6,200 | 15,766 | 6,668 | 269,197 | 74,685 |
| Streamflow | 44,100 | 62,600 | 28,270 | 1,230 | 1,550 | 2,562 5/ | 255,270 | 47,375 |

Figure H-2 (cont.)

Footnotes for table

1/ Instream Flow Approximations (IFA) are quantitative expressions of judgmental estimates of the flow regimes needed to support aquatic life and outdoor recreation.

2/ Surface water supply includes water that has infiltrated to the saturated zone and reappears as surface water, e.g., seepage and springs.

3/ Quantity does not include 6,700 mgd that the Upper Colorado States are obligated to release to Lower Colorado States.

4/ Quantities include flows in closed basins that go into dead lakes and/or playas.

Explanatory notes:

Instream requirements are estimates of the quantities of water needed within the surface water system--streams, etc.

Flow requirements are the largest instream requirement--generally the instream flow approximation (IFA).

Offstream requirements are the quantities of water needed for activities outside of the surface water system. This water is withdrawn from a surface or ground supply source and moved to the location of the activity. From there, the water is returned to the supply source or is consumed -- lost to the region's hydrologic system, most is returned to the atmosphere. The table shows the amount of water consumed by each different activity and the total consumptive requirements for all activities.

Exports are not transports of water from a region. Imports are not transports to a region.

Evaporation is water loss from manmade pond and reservoir surfaces that exceeds precipitation.

Replenishable supply is runoff, some recharges ground water supplies and some replenishes surface supplies. It would be the "natural" streamflow if there were no depletions.

Ground water mining occurs wherever withdrawals from ground water exceed recharge.

Total water supply is the inflow from upstream areas, replenishable surface and ground water, mined ground water, and imports from other regions.

Total water depletions are the sums of water consumed, exports, and evaporation.

Streamflow is the measure of water quantities at a hydrologic region's outflow point(s). It is the balance of the region's total water supply remaining after total water depletions.

Source: U. S. Water Resources Council, The Nation's Water Resources, 1978.

Figure H-3

## Groundwater Withdrawals in Excess of Recharge

| | Groundwater Mined | |
|---|---|---|
| Water Resources Region | Amount (Million gal/day) | Percent |
| Missouri | 2,557 | 25 |
| Arkansas-White-Red | 5,457 | 62 |
| Texas-Gulf | 5,578 | 77 |
| Rio Grande | 657 | 28 |
| Upper Colorado | 0 | 0 |
| Lower Colorado | 2,415 | 48 |
| Great Basin | 591 | 42 |
| Pacific Northwest | 627 | 9 |
| California | 2,197 | 12 |
| Western Regions | 20,079 | |
| Conterminous U.S. | 20,889 | |

Western Regions as a Percentage
of Total U.S.: 96.1

Source: USDA, RCA, 1980.

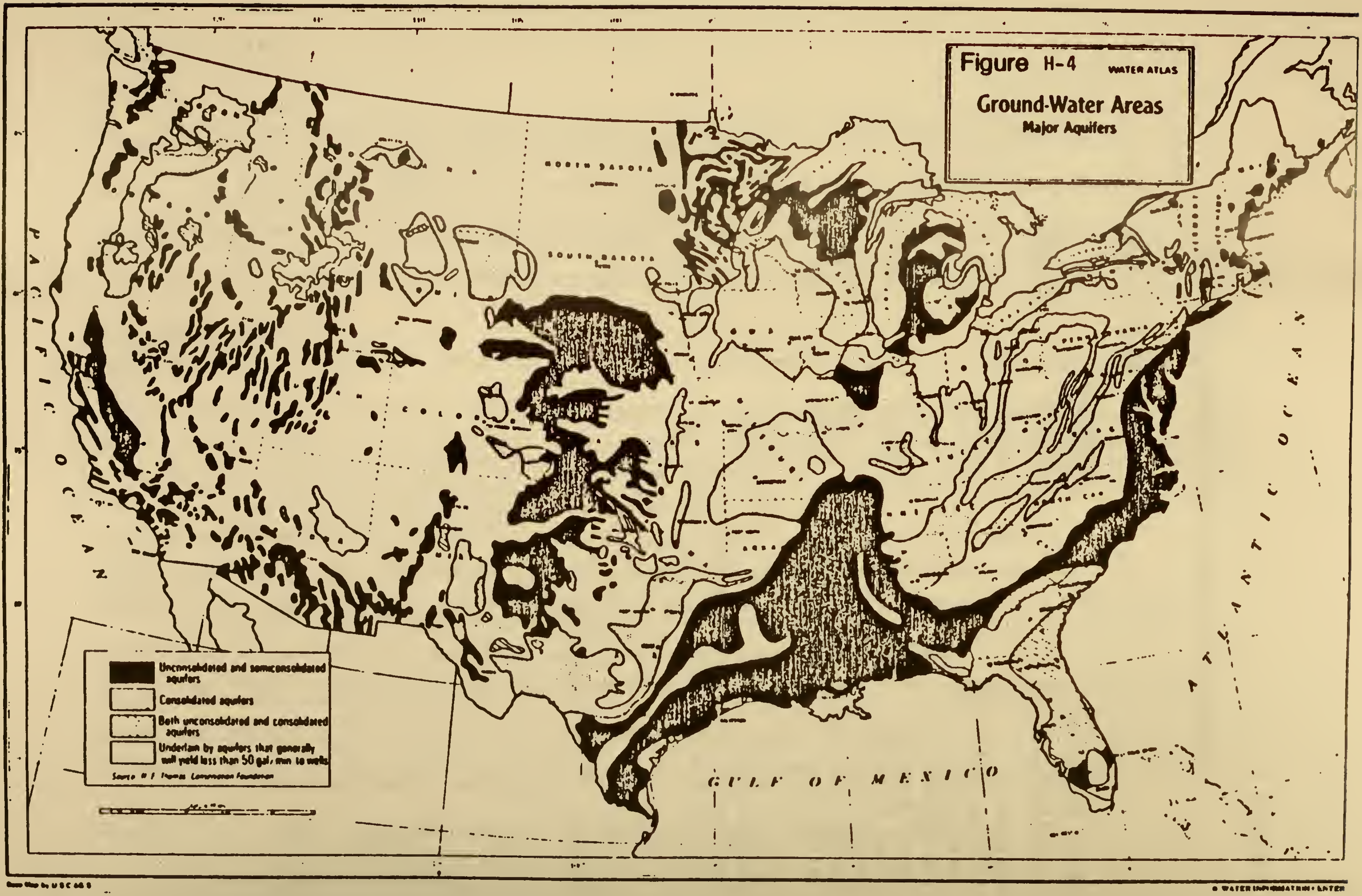
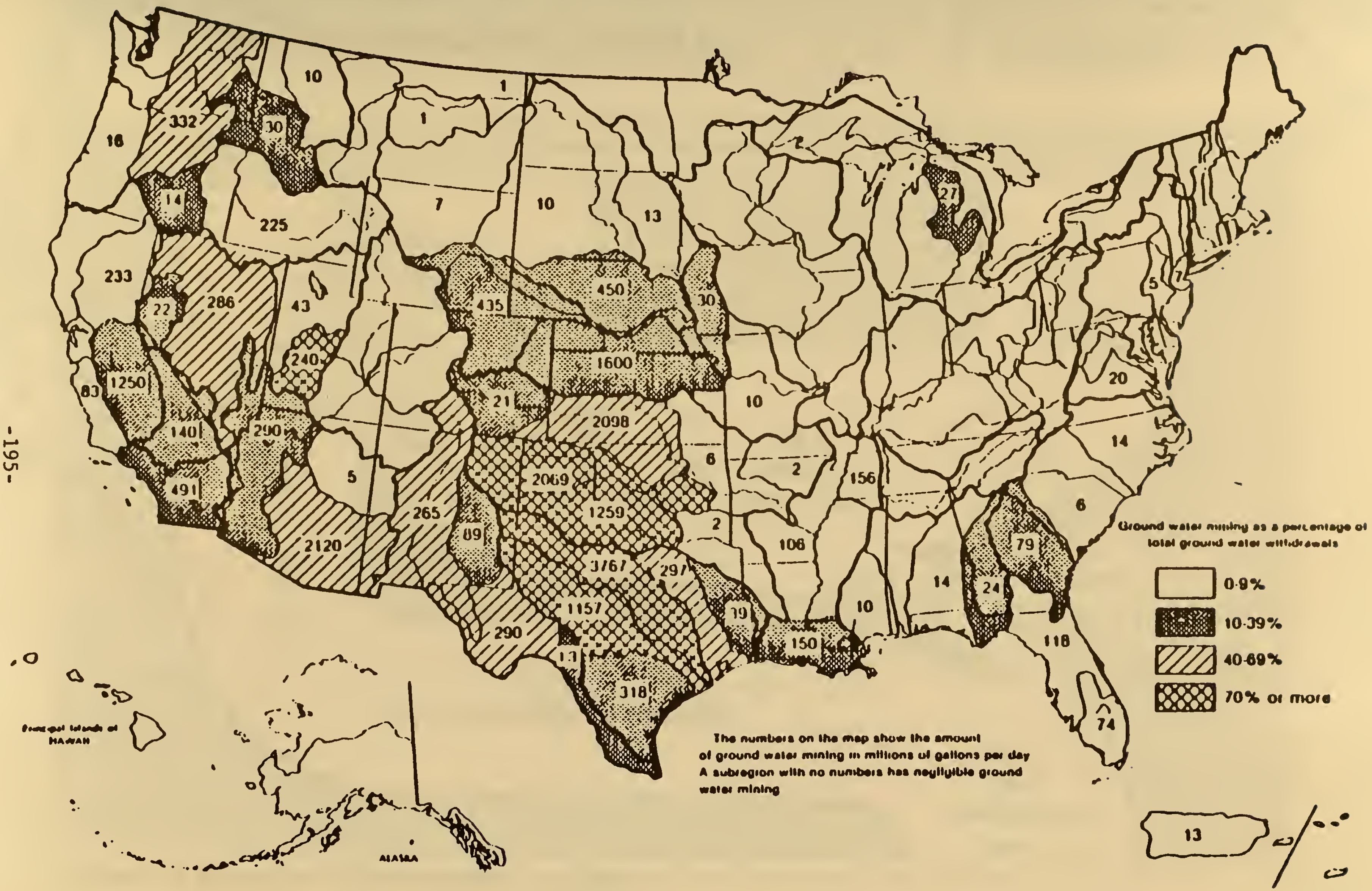


Figure H-4 WATER ATLAS
Ground-Water Areas
Major Aquifers
Unconsolidated and semiconsolidated aquifers
Consolidated aquifers
Both unconsolidated and consolidated aquifers
Underlain by aquifers that generally will yield less than 50 gal/min to wells
Source H. E. Thomas, Conservation Foundation
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
NORTH DAKOTA
SOUTH DAKOTA
© WATER INFORMATION CENTER

Source: James L. Geraghty, et al., Water Atlas of the U.S., Port Washington, NY: Water Information Center, 1973.

Figure H-5



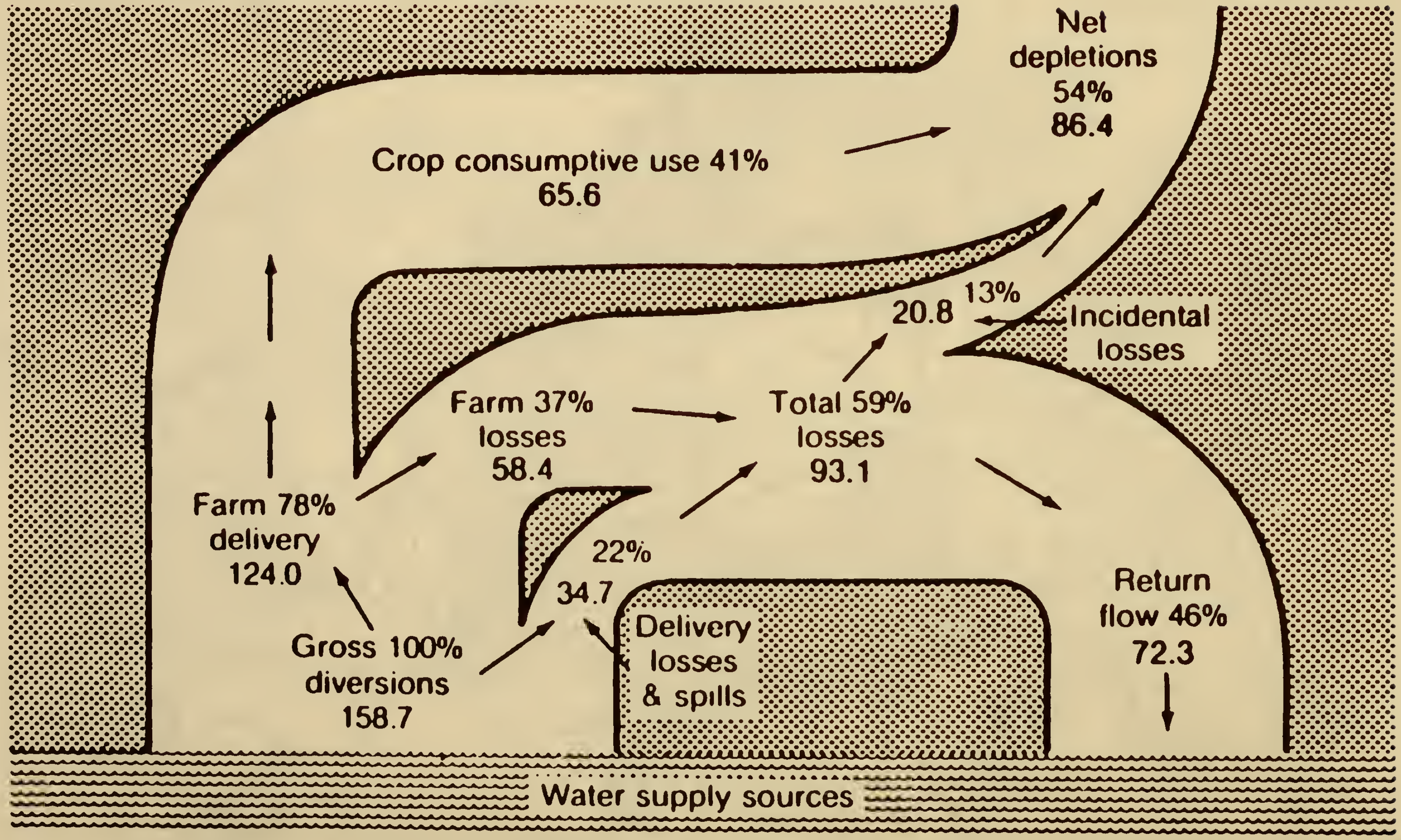
The numbers on the map show the amount of ground water mining in millions of gallons per day A subregion with no numbers has negligible ground water mining

Areas of ground water mining, "1975."

Source: U.S. Water Resources Council, The Nation's Water Resources, 1978.

Figure H-6

(Percent of Diversions - Mil. Gallons Per Day)



Irrigated water budget.

Source: USDA, RCA, 1980.

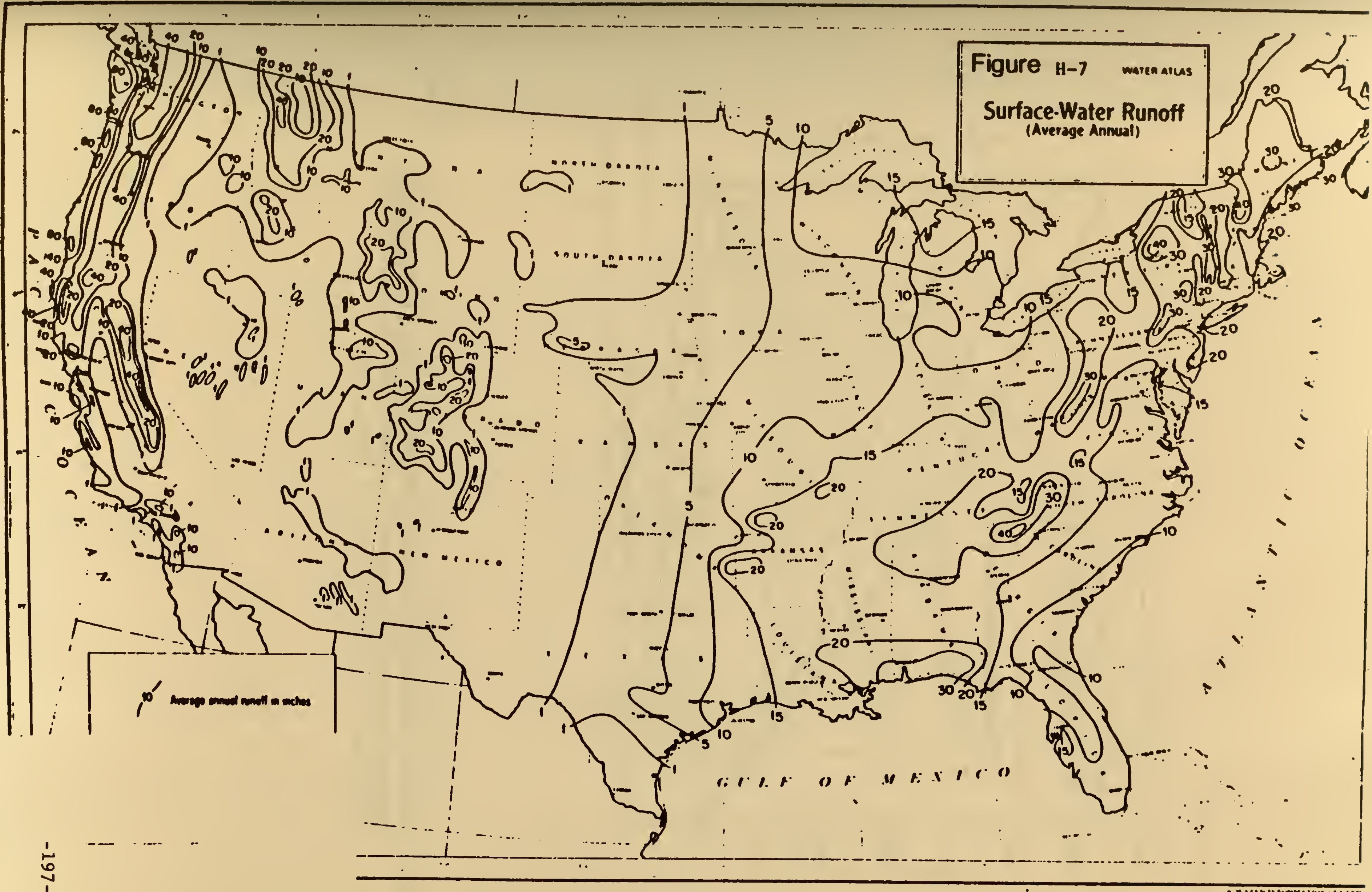
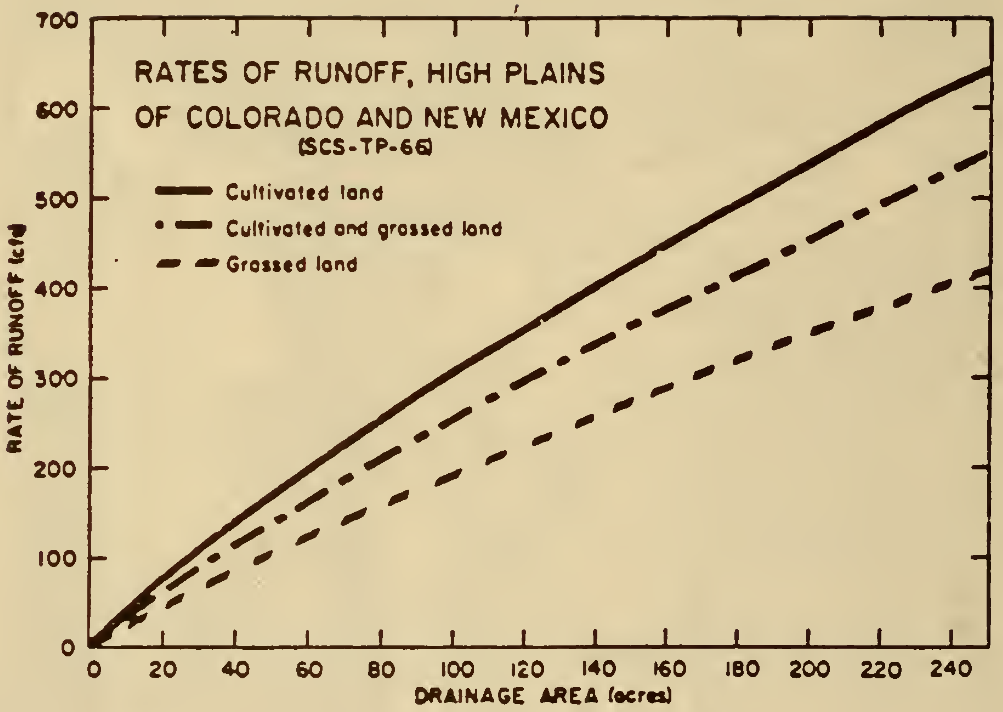


Figure H-7

Surface-Water Runoff (Average Annual)

Source: James L. Geraghty, et al., Water Atlas of the U.S., Port Washington, NY: Water Information Center, 1973, from U.S. Geological Survey data.

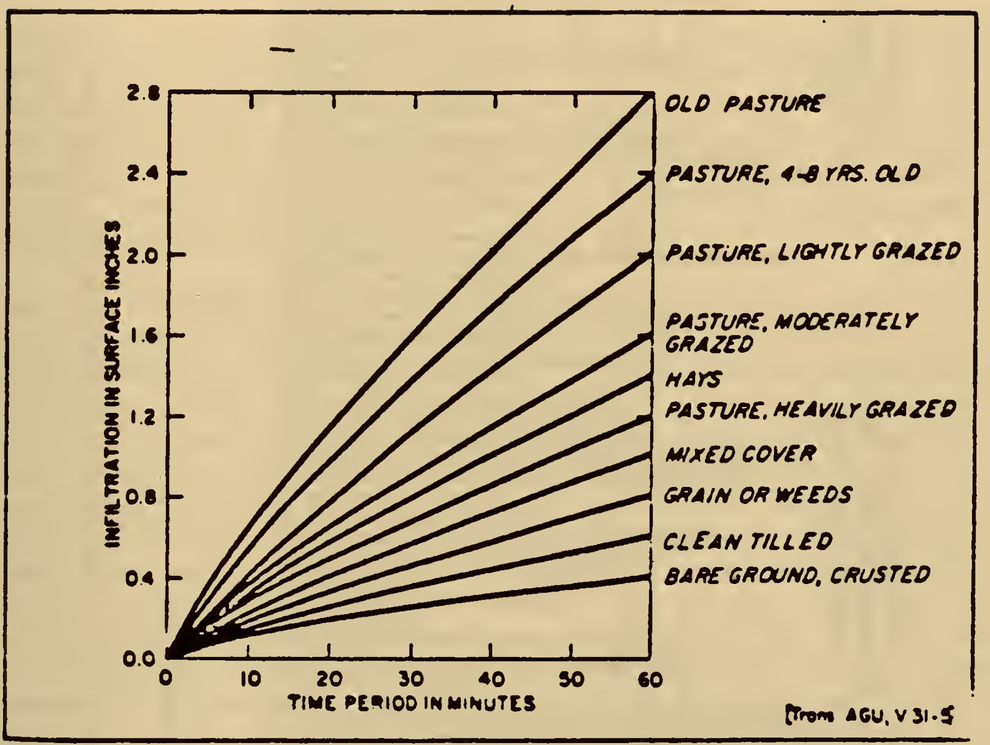
Figure H-8



Land use and treatment effect on 25-year runoff frequencies.

Source: Walter L. Moore and Carl W. Morgan, Effects of Watershed Changes on Streamflow, Austin: Center for Research in Water Resources of the University of Texas, 1969.

Figure II-9

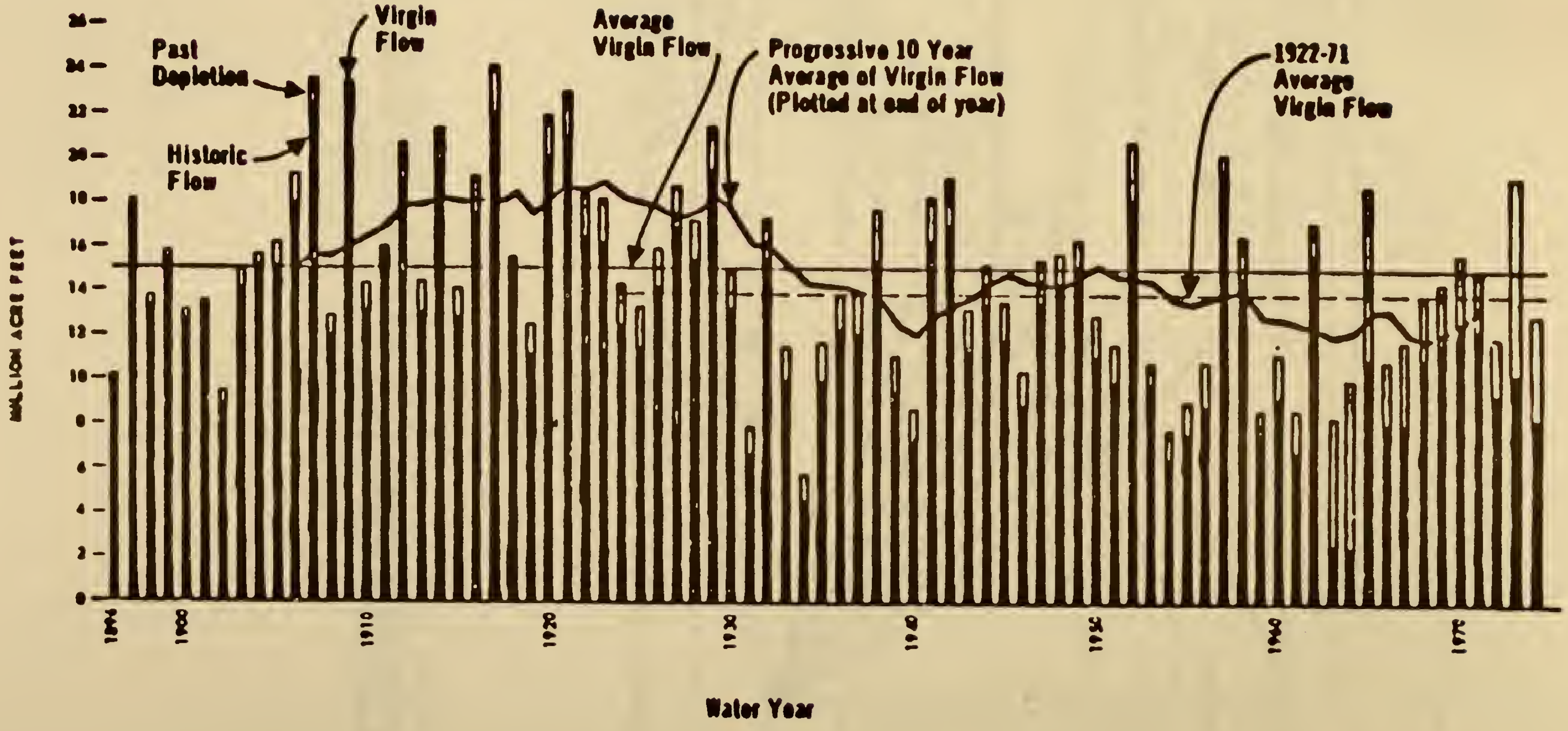


[From AGU, V 31-5

Mass infiltration on Cecil, Madison, and Durham soils based on infiltrometer data.

Source: Walter L. Moore and Carl W. Morgan, Effects of Watershed Changes on Streamflow, Austin: Center for Research in Water Resources of the University of Texas, 1969.

Figure H-10 Colorado River Flow at Lee Ferry, Arizona



Source: U.S. Dept. of the Interior, Bureau of Reclamation, Critical Water Problems Facing the Eleven Western States, April 1975.

## Appendix I: Effect of Social Structure

The composition of a society and the conditions under which it functions affect the reactions of a given population to legislating, funding, and implementing policy proposals.

Some of the human factors influencing the decisionmaking process are age, cultural background, income level, type of community activities, population stability and density, and employment (figures I-1 - I-6). The combination of these factors or the effects of a single one may result in different decisions which could affect environmental quality issues, job opportunities, recreation activities, development of natural resources, community growth, etc.

The perceptions, real or not, of the impact that certain proposed or ongoing activities may have on the survival and fulfillment of individual and community needs and desires are crucial in deciding whether to undertake and/or continue the activities in question. Perceived financial impacts influence the selection of options to a great degree. In a situation in which there are losses of an economic, ecological, political, or any other nature that may threaten individual and/or community survival, security, and esthetic and intellectual needs, the options followed are generally: (a) to modify the cause so as to reduce the frequency of events that result in losses; (b) to modify the process by which the losses occur or to channel the forces of the event; or (c) to modify the loss potential so as to reduce the losses after the event has occurred. The decision to follow either, some, or all of these paths, and to what extent and direction, is a function of the factors mentioned above, as well as others.

Figure I-1

## Population and Population Density

| Region | Population x1,000 | | | | | | | Population per Square Mile | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1930 | 1940 | 1950 | 1960 | 1970 | 1977 | 2000* | 1930 | 1970 | 2000* |
| Great Plains (ND, SD, NE, KS, OK, TX) | 12,854 | 13,153 | 14,448 | 16,811 | 18,780 | 20,870 | 26,487 | 20.3 | 29.6 | 41.8 |
| Mountain (MT, ID, WY, CO, NM, AZ, UT, NV) | 3,702 | 4,150 | 5,075 | 6,855 | 8,282 | 10,031 | 14,732 | 4.3 | 9.7 | 17.2 |
| Pacific (WA, OR, CA) | 8,194 | 9,733 | 14,486 | 20,339 | 25,453 | 27,930 | 34,540 | 25.7 | 79.8 | 108.2 |

*Assumes cohort fertility will approach 2.1 births per woman, and that the 1970-75 interstate migration patterns will continue.

Source: U.S. Bureau of the Census: Statistical Abstracts of the U.S., 1978.

**Figure I-2**

## Percent Population by Age

| Region | 1960 | | | | 1977 | | | |
|---|---|---|---|---|---|---|---|---|
| | Under 5 Years | 5-19 Years | 20-64 Years | 65 Years & Older | Under 5 Years | 5-17 Years | 18-64 Years | 65 Years & Older |
| Great Plains (States) | 11.7 | 28.2 | 51.0 | 9.1 | 7.9 | 22.9 | 58.5 | 10.7 |
| Mountain (States) | 12.8 | 29.6 | 49.9 | 7.7 | 8.8 | 23.6 | 58.5 | 9.1 |
| Pacific (States) | 11.0 | 26.5 | 53.4 | 9.1 | 6.9 | 21.8 | 61.1 | 10.2 |
| Total | | 1960: 44,005,000 | | | | 1977: 58,831,000 | | |

Source: U.S. Bureau of the Census, *Statistical Abstract of the U.S., 1978*.

Figure I-3

## Metropolitan and Nonmetropolitan Area Population*

| Region | Metropolitan Area Population | | | | Nonmetropolitan Area Population | | | |
|---|---|---|---|---|---|---|---|---|
| | Pop. x1,000 | | % of Region | | Pop. x1,000 | | % of Region | |
| | 1960 | 1976 | 1960 | 1976 | 1960 | 1976 | 1960 | 1976 |
| Great Plains (ND, SD, NE, KS, OK, TX) | 9,901 | 13,501 | 58.9 | 65.7 | 6,911 | 7,048 | 41.1 | 34.3 |
| Mountain (MT, ID, WY, CO, NM, AZ, UT, NV) | 3,672 | 5,933 | 53.6 | 60.4 | 3,182 | 3,886 | 46.4 | 39.6 |
| Pacific (WA, OR, CA) | 17,635 | 23,936 | 86.7 | 87.2 | 2,703 | 3,524 | 13.3 | 12.8 |

*Refers to 277 SMSA's as defined in Standard Metropolitan Statistical Areas, 1975, Revised Ed. (Dec. 1975).

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

Figure I-4

## Employment Data, 1970

| State | Number in the Civilian Labor Force | % of Civilian Labor Force Unemployed | Farm Workers the Civilian Labor Force |
|---|---|---|---|
| Arizona | 640,000 | 4.2 | 17,947 |
| California | 7,992,168 | 6.3 | 162,217 |
| Colorado | 862,133 | 4.2 | 32,131 |
| Idaho | 271,593 | 5.2 | 29,224 |
| Montana | 260,649 | 6.2 | 28,465 |
| Nevada | 208,996 | 5.4 | 3,683 |
| New Mexico | 342,482 | 5.7 | 12,373 |
| Oregon | 837,078 | 7.0 | 31,016 |
| Utah | 399,162 | 5.2 | 11,715 |
| Washington | 1,338,513 | 7.9 | 41,344 |
| Wyoming | 129,577 | 4.8 | 11,061 |
| Total | 12,951,570 | 6.0 | 381,176 |

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

Figure I-5

American Indian Population in the Western States

| | 1960 | 1970 |
|---|---|---|
| Great Plains | 118,583 | 178,455 |
| Kansas | | 8,672 |
| Nebraska | | 6,624 |
| North Dakota | | 14,369 |
| Oklahoma | | 98,468 |
| South Dakota | | 32,365 |
| Texas | | 17,957 |
| Mountain | 188,004 | 235,439 |
| Arizona | | 95,812 |
| Colorado | | 8,836 |
| Idaho | | 6,687 |
| Montana | | 27,130 |
| Nevada | | 7,933 |
| New Mexico | | 72,788 |
| Utah | | 11,273 |
| Wyoming | | 4,980 |
| Pacific | 68,116 | 137,914 |
| California | | 91,018 |
| Oregon | | 13,510 |
| Washington | | 33,386 |

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

Figure I-6

## American Indian Population Figures

| | 1960 | % of Total | 1970 | % of Total |
|---|---|---|---|---|
| Great Plains Region (States) | 118,583 | 32 | 178,455 | 32 |
| Mountain Region (States) | 188;004 | 50 | 235,439 | 43 |
| Pacific Region (States) | 68,116 | 18 | 137,914 | 25 |
| Total | 374,703 | 100 | 551,808 | 100 |
| Total Urban Pop. | 104,917 | 28 | 248,314 | 45 |
| Total Rural Pop. | 269,786 | 72 | 303,494 | 55 |

Figures extrapolated from U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

## Appendix J: Economic Concerns

The impact of desertification on arid and semiarid land economic systems may be quite high, but data is scarce, sketchy, and far from definitive. Nevertheless, the need for even a gross assessment of such impacts, especially on the agricultural and supporting industries, should be emphasized. The possible spread of desertification and degradation of the land and water resource base of the Western United States could adversely affect economic growth in that region. This is true in part since agricultural production is an important component of the economic base (table J-1) and desertification would likely adversely affect agriculture. Deterioration of the water resources would affect other activity as well, placing strains on industrial, urban, and energy development (table J-2). It is also important to ascertain the value of lost systems, and the costs of various levels of rehabilitation, conservation, control and prevention practices. These cost/benefit studies are essential in deciding which action should be taken and to what extent.

What makes the evaluation of the impact of localized desertification especially difficult is the interdependence among all economic sectors, and the ripple effect that occurs throughout the regional and national economic systems. Table J-3 shows the estimated total impact of a $100,000 loss in dryland crop production on Texas industries. The table reveals that the ripple spreads to become a $374,000 loss. A loss of this nature is common in the Western U. S. due to the highly variable annual weather conditions. Table J-4 shows what has happened in the past when drought hit the Western U. S. in the 1930s and 1950s. Crop failures increased dramatically, and related business and services suffered economic damage as a consequence.

Another factor of primary importance in deciding which management, conservation, and control practice to follow is the energy budget of each alternative. For example, in Nebraska alone, 2.4 million acres are now irrigated by center-pivot irrigation systems. Each year, 83 million gallons of diesel fuel are necessary merely to drive the pivot, not including pumping of groundwater or other related energy-consumptive uses. There are now nearly 55,000 center-pivot irrigation systems in the U. S., and this number is increasing rapidly each year (figures J-5 and J-6).

Another economic consideration is the increasingly intense use of the land, augmented by demand on the groundwater supply and associated problems such as salinity buildup which lead to an increased energy budget. In such a case,, the energy needed to augment water supplies and control salinity, added to the energy necessary to maintain the level of production (more fertilizers and pesticides, as well as water treatment costs), should be calculated. These energy costs are important determinants in deciding on the continuation, termination, or change of procedures.

Financial systems can influence economic climate of an impacted area so as to support economic growth and to mitigate economic shocks. For example, short-term loans are now available to meet seasonal peaks in loan demands often experienced in agricultural and recreation-oriented areas.

Some issues of importance to the economic growth and financial stability of regions subject to drought and desertification include:

1) The impact of drought and desertification on industrial, urban, energy, and recreation-related economic activity and development plans in the semiarid and arid Western United States--along with the consequent impact on credit demands;

2) The impact of drought and desertification on the rural infrastructure, including those firms that supply inputs and services to farm producers, as well as those firms marketing farm products;

3) The ability of farm and ranch operators to service debts from potentially reduced case flows associated with less water-intensive agriculture;

4) The stability of financial institutions in the event of widespread loan restructuring or default as a result of reduced economic activity related to drought and desertification;

5) The appropriate role for government to play in providing emergency credit and insuring private sector losses associated with desertification;

6) The spillover effects of drought and desertification in the Western States to otherwise unaffected areas of the country (i.e., reduced food production, reduced energy production, reduced demand for goods and services, diminished recreation opportunities, lower foreign exchange earnings if agricultural exports suffer).

These issues require both qualitative and quantitative analysis. State and regional input-output models as well as large-sector models will support such analysis. Some of the required analytical work that may already have been done by universities and State or regional agencies should be brought together to assess these and other pertinent issues.

Figure J-1

## 1977 CASH RECEIPTS AND HOME CONSUMPTION VALUES

(IN BILLIONS OF DOLLARS)

| | USA | 17 Western States | Percent |
|---|---|---|---|
| **Livestock** | 48.5 | 19.15 | 40.7 |
| **Crops** | 48.9 | 22.08 | 45.1 |
| **Total** | 97.4 | 41.23 | 42.3 |

Source: USDA, Agricultural Statistics, 1978.

Figure J-2

Trade - Sales and Payroll

(billions of dollars)

| Region | Wholesale Trade Sales* 1963 | Wholesale Trade Sales* 1972 | Wholesale Trade Payroll 1972 | Retail Trade Sales* 1963 | Retail Trade Sales* 1972 | Retail Trade Payroll 1972 |
|---|---|---|---|---|---|---|
| Great Plains | 30.8 | 66.0 | 3.1 | 22.3 | 43.7 | 4.8 |
| Mountain | 9.9 | 21.3 | 1.2 | 10.1 | 21.5 | 2.5 |
| Pacific | 45.0 | 86.8 | 4.8 | 33.6 | 62.6 | 8.2 |

*All establishments

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978

Figure J-3

### Estimated Total Annual Impact of $100,000 Loss in Dryland Crop Production on Texas Industries

| | Selected Texas Industries | Amount Lost from Decreased Output of Dryland Crops |
|---|---|---|
| 1. | Retail trade | $ 26,390 |
| 2. | Finance, insurance and real estate | 19,300 |
| 3. | Other services and education | 14,560 |
| 4. | Agricultural services | 18,040 |
| 5. | Wholesale trade | 14,280 |
| 6. | Agricultural chemicals | 9,300 |
| 7. | Petroleum refining | 9,120 |
| 8. | Electric services | 2,630 |
| 9. | Motor freight and storage | 3,360 |
| 10. | Communications | 2,270 |
| 11. | All other sectors, incl. households* | 254,750 |
| | | $374,000 |

*Includes the direct loss of $100,000

Source: ASCE, Water Conservation Needs and Implementing Strategies, 1979.

Figure J-4

## Cropland Used for Crops; Crop Failure

(millions of acres)

| | | Cropland Used for Crops | Crop Failure |
|---|---|---|---|
| Great Plains | 1939 | 128.0 | 13.9 |
| | 1956 | 131.7 | 14.3 |
| | 1977 | 130.4 | 4.5 |
| Mountain | 1939 | 25.8 | 2.7 |
| | 1956 | 35.7 | 3.0 |
| | 1977 | 36.0 | 1.1 |
| Pacific | 1939 | 17.8 | 0.5 |
| | 1956 | 20.8 | 0.4 |
| | 1977 | 20.7 | 0.2 |

Note: 1939 and 1956 were the heights of the 1930's and 1950's Dust Bowls.

Source: Donald D. Duros and Evelyn T. Black, Changes in Farm Production and Efficiency, USDA, November 1978.

Figure J-5

## Energy Costs for Various Irrigation Systems (Diesel Fuel Only)

|  | Total Lift Feet | Field Eff. % | Pot. Eff. | Water per Acre Inches | Fuel/Ac. Gal. | Cost of Energy per Acre 1977 | Cost of Energy per Acre 1979 |
|---|---|---|---|---|---|---|---|
| Traveling Big Guns | 389 | 70 | 75 | 17 | 68.7 | $28.16 | $56.32 |
| Center-Pivot | 273 | 80 | 85 | 15 | 42.5 | 17.43 | 34.86 |
| Skid-tow | 215 | 75 | 80 | 16 | 35.8 | 14.67 | 29.34 |
| Gated Pipe w/o reuse | 120 | 60 | 70 | 20 | 25.1 | 10.27 | 20.54 |
| w/reuse | 120 | 70 | 85 | 17 | 21.3 | 8.71 | 17.43 |
| Auto-surface | 120 | 85 | 92 | 14 | 17.5 | 7.18 | 14.35 |
| Drip-Trickle | 150 | 85 | 92 | 14 | 21.7 | 8.89 | 17.80 |

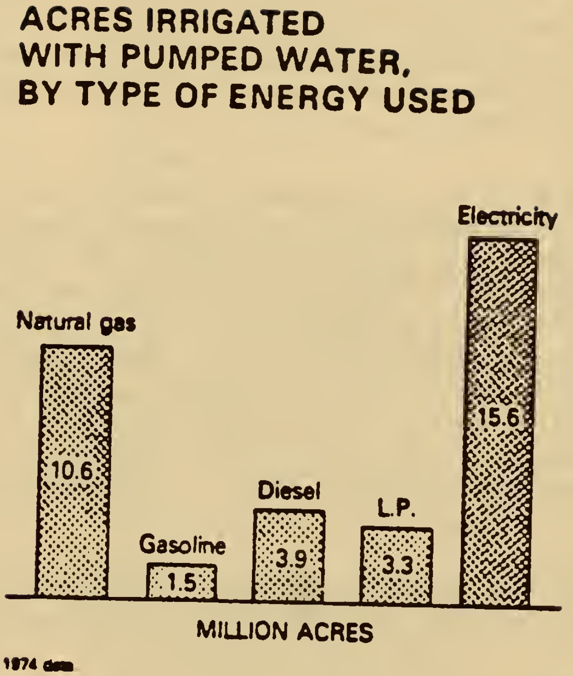
Based on: 100 ft. of lift from ground water reservoir;

12 inches of net water application;

$0.41 per gallon diesel fuel - 1977;
$0.82 per gallon diesel fuel - 1979.

Source: ASCE, Water Conservation Needs and Implementing Strategies, 1979.

Figure J-6



Source: USDA, 1978 Handbook of Agricultural Charts.

## Appendix K: Federal Institutional Responsibility

### Introduction

The legal and institutional arrangement presented here provide a framework for cooperation with other similar State entities. However, such a framework is not always used to its fullest and best extent. For example, one study found that the main water problems of arid and semiarid lands existed not because of technical incapacity, but because of deficiencies in policies and procedures.

The goals and values of closely-related institutions at different levels of government are seen as clashing. A trend toward greater centralization combined with a heightened concern for natural and wildlife resources has fostered competition rather than cooperation between the States and the Federal Government. Federal advocates argue that theirs is the broader jurisdictional reach.and that, for example, populations of animals should be subjected only to integrated and systematic management of a sort which cannot by its nature be applied at the State level. In rebuttal, the States maintain that they, after all, are on location in the field with the personnel and the initiative to deal with the problems at ground level.

What follows briefly describes the agencies' responsibilities and capabilities to carry out the missions mandated by existing legislation.

expertise in a proposal. Those interested may then contact the potentially involved agencies to obtain information on the issues and to participate in the NEPA process.

The list is organized into four broad categories: pollution control, energy, land use, and natural resource management. Because some activities may fall into more than one of these categories, users of the list should consult all pertinent entries.

**Index**

*I. Pollution Control*

A. Air Pollution.
B. Water Pollution.
C. Solid Waste.
D. Noise.
E. Radiation.
F. Hazardous Substances.
Toxic Materials.
Food Additives and Contamination of Food Stuff.
Pesticides.

*II. Energy*

A. Electric Power.
B. Petroleum.
C. Natural Gas.
D. Coal and Minerals.

*III. Land Use*

A. Land Use Changes, Planning, and Regulation of Land Development.
B. Public Land Management.
C. Coastal Areas.
D. Environmentally Critical Areas.
E. Community Development.
Built-up or Distressed Areas.
Density and Congestion Mitigation.
Neighborhood Character.
F. Historic, Architectural, and Archeological Preservation.
G. Outdoor Recreation.

*IV. Natural Resource Management*

A. Weather Modification.
B. Waterway Regulation and Stream Modification.
C. Soil and Plant Conservation and Hydrology.
D. Fish and Wildlife.
E. Renewable Resources.
F. Energy and Natural Resources Conservation.

### I. Pollution Control

#### *A. Air Pollution*

*Department of Agriculture*

Forest Service (effects of air pollution on vegetation and visibility; fire smoke management).

Soil Conservation Service (effects of air pollution on vegetation; wind erosion).

*Department of Commerce*

National Oceanic and Atmospheric Administration (meteorological and climatological research and monitoring; urban pollution).

*Department of Defense*

Department of the Air Force (pollution from military aircraft).

*Department of Energy*

Energy Information Administration (emissions from energy sources).

• Approvals of plans for power plants and major fuel-burning facilities:

Federal Energy Administration Act of 1974, 15 U.S.C. 761–790h.

Powerplant and Industrial Fuel Use Act of 1978, Pub. L. 95–620, 92 Stat. 3289.

*Department of Health, Education, and Welfare*

Public Health Service:

Center for Disease Control (effects of air pollution on health).

National Institutes of Health (effects of air pollution and health).

*Department of Housing and Urban Development (housing and community planning)*

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands).

Bureau of Mines (air pollution for mining and minerals processing and fossil and gaseous fuel combustion).

Fish and Wildlife Service (effects of air pollution on fish and wildlife).

Geological Survey (emissions from outer-continental shelf lease operations).

Heritage Conservation and Recreation Service (recreation).

National Park Service (visibility in national parks).

Office of Surface Mining Reclamation and Enforcement (surface mining).

*Department of Labor*

Mining Safety and Health Administration (airborne pollutants in workplace (mines)).

Occupational Safety and Health Administration (airborne pollutants in workplace.

*Department of Transportation*

Coast Guard (cargo tank venting and vapor recovery systems).

Federal Aviation Administration (aircraft emissions).

Federal Highway Administration (highway related air quality impacts; vehicle emissions).

Federal Railroad Administration (locomotive emissions).

Urban Mass Transportation Administration (urban transportation systems).

*Environmental Protection Agency (effects of air pollution on public health and welfare; air quality criteria and standards, vehicle and aircraft emissions)*

• Prevention of significant deterioration of air quality, 42 U.S.C. 7470 *et seq.*

• Application for primary non-ferrous smelter order, 42 U.S.C. 7419.

• Assuring that federal projects conform to state implementation plans under Clean Air Act, 42 U.S.C. 7616.

*National Aeronautics and Space Administration (advanced technology for remote sensing of air quality parameters and for reduction of aircraft engine emissions)*

*Nuclear Regulatory Commission (radioactive substances)*

*Tennessee Valley Authority (Tennessee Valley region)*

#### *B. Water Pollution*

Water Quality

*Department of Agriculture*

Agriculture Stabilization and Conservation Service (agricultural lands).

Forest Service (National Forest lands).

Soil Conservation Service (watershed protection)

*Department of Commerce*

Maritime Administration (marine pollution from ships).

National Oceanic and Atomospheric Administration (management and protection of coastal and marine resources.

*Department of Defense*

Army Corps of Engineers:

• Rules governing work or structures in or affecting navigable waters of the United States, 33 U.S.C. 401, 403 and 419

• Permits for river and harbor improvement projects, 33 U.S.C. 541.

• Authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or tributary of a navigable water 33 U.S.C. 407.

• Permits for private projects to improve navigable waters, 33 U.S.C. 565.

• Permits for discharges of dredged or fill materials into navigable waters, 33 U.S.C. 1344.

• Permits for transportation of dredged materials for dumping into ocean waters, 33 U.S.C. 1413.

Department of Navy (ship pollution control).

*Department of Energy (energy programs)*

*Department of Health, Education, and Welfare*

Public Health Service (effects of pollution on health).

*Department of the Interior*

Bureau or Indian Affairs (Indian lands).

Bureau or Land Management public lands, coastal zone management, outer continental shelf).

Bureau of Mines (mining activities).

Bureau of Reclamation (public works).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey (hydrology).

Heritage Conservation and Recreation Service (effects on historic or recreational values).

National Park Service (National Parks).

Office of Surface Mining Reclamation and Enforcement (hydrologic balance in surface mining activities).

Office of Water Research and Technology (water resources planning)

Department of Transportation.

Assistant Secretary for Policy and International Affairs (environmental review of departmental programs).

Coast Guard (oil spills, ship sanitation):

- Tanker construction, equipment, manning, operation. 46 U.S.C. 391a.
- Oil and hazardous substances discharge prevention. 33 U.S.C. 1321.
- Pollution prevention (33 CFR 151, 154–6).
- Vessel navigation, waterfront facility regulations. 33 U.S.C. 1221 (50 U.S.C. 191).
- Certification of marine sanitation devices. 33 U.S.C. 1322 (33 CFR 159).

*Environmental Protection Agency (treatment works; effluent limitations; oil and hazardous substance discharges)*

- Permits for discharge of specific pollutants under aquaculture project. 33 U.S.C. 1328.
- Permits for disposal of sewage sludge. 33 U.S.C. 1345.
- Oil spill prevention, containment and countermeasure plans (prepared by facility owner/operator). 33 U.S.C. 1321, 1361 (40 CFR 1112.7).
- Permits for treatment, storage or disposal of hazardous wastes. 42 U.S.C. 6925.
- Temporary underground injection permits. Safe Drinking Water Act. 41 U.S.C. 300h(C)(1).
- National Pollutant Discharge Elimination System (NPDES) permits. 33 U.S.C. 1342.

*Federal Maritime Commission*

- Certificates of financial responsibility for water pollution. 33 U.S.C. 1321 (46 CFR Part 542); 42 U.S.C. 1643 (46 CFR Part 543), 43 U.S.C. 1815 (46 CFR Part 544).

*National Aeronautics and Space Administration (advanced technology for remote sensing of water quality)*

*Nuclear Regulatory Commission (radioactive substances)*

*Tennessee Valley Authority (Tennessee Valley Region)*

*Water Resources Council (principles and standards)*

River Basin Commissions (as geographically appropriate)

### *Pollution of Marine Resources*

*Department of Commerce*

Maritime Administration (port, coastal and ocean pollution):

- Merchant vessels, polluting discharges and dumping. 46 U.S.C. 1101, *et seq.*
- Port operations, polluting discharges, and dumping. 46 U.S.C. 867 (41 Stat. 992).

National Oceanic and Atmospheric Administration (coastal zone management; ocean pollution).

*Department of Defense*

Army Corps of Engineers:

- Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401, 403 and 419.
- Permits for river and harbor improvement projects. 33 U.S.C. 541.
- Permits for private projects to improve navigable waters. 33 U.S.C. 5651.
- Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Permits for transportation of dredged materials for dumping into ocean waters. 33 U.S.C. 1413.
- Authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or tributary of a navigable water. 33 U.S.C. 407.
- Regulation of artificial islands, installations and devices on the outer continental shelf. 43 U.S.C. 1333(e)

Department of the Navy (oceanography; pollution from ships).

*Department of Energy (energy programs)*

*Department of Health, Education, and Welfare*

Public Health Service (effects on health).

Food and Drug Administration (shellfish sanitation, contamination of fish and shellfish with toxics).

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands):

- Coral harvesting (outer continental shelf). 43 U.S.C. 1334 (43 CFR 6224).
- Mineral leasing on the outer continental shelf. 43 U.S.C. 1331–1343.

Bureau of Mines (ocean mining).

Fish and Wildlife Service (effects on sport fisheries).

Geological Survey:

- Permits for geological and geophysical exploration on outer continental shelf. 43 U.S.C. 1340 (30 CFR 251).
- Permits for exploration and development activities on federal oil and gas leases on the outer continental shelf. 43 U.S.C. 1331 *et seq.* (30 CFR 250).
- Estuarine Areas Act. 16 U.S.C. 1224.

Heritage Conservation and Recreation Service (effects on historic and recreational values of marine resources).

Ocean Mining Administration (ocean mining).

*Department of State (international marine resource issues)*

*Department of Transportation*

Coast Guard (ocean dumping enforcement, and marine resource protection).

*Environmental Protection Agency*

- Permits for ocean discharges. 33 U.S.C. 1343.
- Discharge of specific pollutants under aquaculture project. 33 U.S.C. 1328.
- Permits for disposal of sewage sludge. 33 U.S.C. 1345.
- Permits for transportation of ocean discharge materials. 33 U.S.C. 1412, 1414.

*National Aeronautics and Space Administration (advance technology for remote sensing of water quality)*

*Nuclear Regulatory Commission (radioactive substances)*

*Water Resources Council (principles and standards for water plans)*

River Basin Commissions (as geographically appropriate).

### *C. Solid Waste*

*Department of Agriculture*

Forest Service (National Forests an. Grasslands).

Soil Conservation Service (watershed protection).

*partment of Commerce*

aritime Administration (marine pollution from ships).

*Department of Defense*

Army Corps of Engineers:
- Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401, 403 and 419.
- Discharge of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Transportation of dredged materials for dumping into ocean waters. 33 U.S.C. 1413.

*Department of Health, Education, and Welfare*

Public Health Service:

Center for Disease Control (effects on health).

Food and Drug Administration (contamination of food resulting from disposal of municipal and industrial waste treatment sludge).

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public ds).

ureau of Mines (mineral waste, mine acid waste, municipal solid waste, recycling).

Geological Survey (geologic and hydrologic effects).

National Park Service (National Parks).

Office of Surface Mining Reclamation and Enforcement (surface mining wastes).

*epartment of Transportation*

Coast Guard (ship sanitation).

*nvironmental Protection Agency (solid wastes and recycling—generally)*

- Permits for disposal of sewage ludge. 33 U.S.C. 1345.
- Control and disposal of solid waste. — U.S.C. ———.
- Resource Conservation and ecovery Act. 42 U.S.C. 6964 (40 CFR 3. 3. 255).
- Permits for treatment, storage, or isposal of hazardous wastes. 42 U.S.C. 925.
- Use of restricted toxic substances— emptions from rules/regulations. 15 .C. 2601–2629.

Transportation and handling of zardous substances.— U.S.C. ———.

*General Services Administration (public buildings)*

*Nuclear Regulatory Commission (radioactive waste)*

- Licensing of radioactive wastes. 42 U.S.C. 2071–2114, 5842 (10 CFR Parts 20, 40).

*Tennessee Valley Authority (Tennessee Valley region)*

*Water Resources Council*

River Basin Commissions (as geographically appropriate).

*D. Noise*

*Department of Agriculture*

Forest Service (National Forests and Grasslands).

*Department of Commerce*

National Bureau of Standards (measurements, standards, and methods).

*Department of Defense*

Department of the Air Force (military aircraft noise).

*Department of Health, Education, and Welfare (effects on health)*

*Department of Housing and Urban Development*

Office of Community Planning and Development (environmental criteria and standards for housing and land use).

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands):
- Lease of public lands for airports. 49 U.S.C. 211–214 (43 CFR 2640).
- Off-road vehicle noise. (E.O. 11644). — FR ———.

Bureau of Mines (mine noise, blasting and vibration).

*Department of Labor*

Mining Safety and Health Administration (noise in the workplace).

Occupational Safety and Health Administration (noise in the workplace).

*Department of Transportation*

Federal Aviation Administration:

Office of Environment and Energy:
- Airport construction, alteration, etc. 49 U.S.C. 1350, 1354, 1355 (14 CFR 157).

Federal Highway Administration (traffic and motor carrier noise).

Federal Railroad Administration (railroad noise).

Urban Mass Transportation Administration (transit noise).

*Environmental Protection Agency*

- Noise Control Act of 1972. 42 U.S.C. 4901–4918.
- National Aeronautics and Space Administration (advance technology for reduction of aircraft noise)

*E. Radiation*

*Department of Commerce*

National Bureau of Standards (measurements, standards, methods and data).

*Department of Energy*

Office of Energy Technology (nuclear energy).

*Department of Health, Education, and Welfare*

Public Health Service:

Food and Drug Administration (health and safety: contamination of food with radioactive materials).

National Institutes of Health (health).

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands):
- Leases for phosphate and uranium. — U.S.C. ———.
- Leases for withdrawal of public lands for radiation waste depository (deep burial). — U.S.C. ———.

Bureau of Mines (uranium mines).

Geological Survey (waste disposal).

*Department of Labor*

Mining Safety and Health Administration (uranium mines).

Occupational Safety and Health Administration (worker exposure to sources of radiation not covered by the Department of Energy).

*Department of Transportation*

Federal Highway Administration:

Bureau of Motor Carrier Safety (enforcement of hazardous materials regulation for highway transportation in interstate commerce).

*Environmental Protection Agency (radioactive air emissions)*

*Nuclear Regulatory Commission (radiation effects—generally)*

- Licenses for special nuclear material. 42 U.S.C. 2073–2078 (10 CFR Part 70).
- Licenses for source material. 42 U.S.C. 2091–2099 (10 CFR Part 40).
- Licenses for by-product material. 42 U.S.C. 2111–2114 (10 CFR Parts 30–35).
- Licensing for utilization or production facilities for industrial or commercial purposes. 42 U.S.C. 2131–2133 (10 CFR Part 50).

• Licensing utilization or production facilities for medical therapy and research and development. 42 U.S.C. 2134 (10 CFR Part 50).

• Nuclear power reactor operators license. 42 U.S.C. 2137 (10 CFR Part 55).

• Licensing and regulating Department of Energy demonstration reactors. 42 U.S.C. 5842.

• Licensing Department of Energy facilities for receipt and storage of high-level radioactive wastes. 42 U.S.C. 5842.

### *F. Hazardous Substances*

Toxic Materials

*Consumer Product Safety Commission (consumer product safety)*

*Department of Agriculture*

Agricultural Marketing Services (consumer protection).

Animal and Plant Health Inspection Service (disease vectors).

*Department of Commerce*

Maritime Administration (port, coastal and ocean pollution):

• Merchant vessels, polluting discharges and dumping. 46 U.S.C. 1101 *et seq.*

• Port operations, polluting discharges and dumping. 46 U.S.C. 867 (41 Stat. 992).

National Bureau of Standards (measurements, standards methods and data.)

National Oceanic and Atmospheric Administration (coastal and marine resources management and protection).

*Department of Defense (military operations)*

*Department of Health, Education, and Welfare*

Public Health Service:

Center for Disease Control (health issues).

Food and Drug Administration (contamination of food).

National institutes of Health (health issues).

*Department of Housing and Urban Development*

• Office of Policy Development and Research (lead-based paint poisoning prevention research).

*Department of the Interior*

Bureau of Indian Affairs (Indians and Indian lands).

Bureau of Land Management (public lands).

Bureau of Mines (disposal methods for selected milling and mine wastes).

Fish and Wildlife Service (effects on fish and wildlife resources).

National Park Service (National parks).

Office of Surface Mining Reclamation and Enforcement (surface mining).

*Department of Labor*

Mining Safety and Health Administration (mining hazards).

Occupational Safety and Health Administration (workplace hazards).

*Department of Transportation*

Coast Guard:

• Transportation of hazardous materials by vessel. 46 U.S.C. 170, 375, 391a, 416; 49 U.S.C. 1655, 1803, 1804, 1808, 50 U.S.C. 198.

• Navigation and waterfront facility regulation. 33 U.S.C. 1221, 1224, 1321; 50 U.S.C. 191.

• Hazardous substance discharge to navigable waters. 33 U.S.C. 1321.

Federal Highway Administration.

Bureau of Motor Carrier Safety (hazardous material transportation in interstate commerce).

Federal Railroad Administration (railroad transport).

Research and Special Programs Administration (hazardous cargo, pipelines).

Materials Transportation Bureau:

• Transportation of hazardous materials. 42 U.S.C. 1805–1806.

• Permits for facilities to handle hazardous materials. 42 U.S.C. 1805–1806.

*Environmental Protection Agency (hazardous air and water pollutants)*

• Permits for treatment, storage or disposal of hazardous wastes. 42 U.S.C. 6925.

• Use of restricted toxic substances—exemptions from rules/regulations. 15 U.S.C. 2601–2629.

• Transportation and handling of hazardous substances. —— U.S.C. ——.

*Food Additives and Contamination of Foodstuffs*

*Department of Agriculture*

Food Safety and Quality Service (meat and poultry products).

*Department of Health, Education, and Welfare*

Public Heath Service.

Food and Drug Administration (effects on health).

*Environmental Protection Agency (effects of pollution)*

*Pesticides*

*Department of Agriculture*

Animal Plant Health and Inspection Service (control of animal and plant pests).

Food Safety and Quality Service (consumer protection).

Forest Service (National Forest and Grasslands).

Science and Education Administration (biological controls, food and fiber production).

Soil Conservation Service (watershed protection).

*Department of Commerce*

Maritime Administration (merchant ship operations).

National Oceanic and Atmospheric Administration (effects on marine life and the coastal zone).

*Department of Defense*

Armed Forces Pest Management Board (pesticide use on DOD lands, facilities and equipment; control of disease vectors).

Armed Services Explosive Safety Board (control of pests for munitions and explosive devices).

*Department of Health, Education, and Welfare*

Public Health Service:

Center for Disease Control (effects on health)

Food and Drug Administration (contamination of food)

*Department of the Interior*

Bureau of Indian Affairs (indian lands).

Bureau of Land Management (public lands).

—Bureau of Reclamation (irrigated lands).

Fish and Wildlife Service (effects on fish and wildlife resources).

National Park Service (national Parks).

*Department of Labor*

Occupational Safety and Health Administration (worker exposures during manufacture of pesticides).

*Department of Transportation*

• Permits for transportation of hazardous materials. 49 U.S.C. 1805–1806.

• Approval for shipments of Class A explosives. 46 U.S.C. 170(7).

• Permits for facilities to handle hazardous materials. 49 U.S.C. 1805–1806.

Coast Guard:

• Permits for transportation of hazardous substances. 46 U.S.C. 170, 391a.

• Navigation and waterfront facility regulation. 33 U.S.C. 1221, 1321; 50 U.S.C. 191.

Federal Aviation Administration (transport by air).

leral Highway Administration
eau of Motor Carrier Safety
icide transport in interstate commerce)

Federal Railroad Administration (transport by rail).

Research and Special Programs Administration.

Materials Transportation Bureau (transport).

*Environmental Protection Agency*

• Permits for treatment, storage or disposal of hazardous wastes. 42 U.S.C. 6925.

• Certification of pesticide users. 7 U.S.C. 135–136y (40 C.F.R. Part 171).

• Registration of pesticides. 7 U.S.C. 163a.

• Experimental Use Permits. 7 U.S.C. 163a (40 C.F.R. Part 172).

## II. Energy

### *A. Electric Power Development, Generation and Transmission, and Use*

*Department of Agriculture*

Forest Service (National Forests and Grasslands).

• Rights-of-way for electrical, communication, water facilities and roadways. 16 U.S.C. 522 *et seq.* (CFR 251.50).

ral Electr ation Adminsitration
l areas)

Electrical generation and transmission projects. 7 U.S.C. 901 *et seq.*

*Department of Defense*

Army Corps of Engineers (Hydro):

• Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 403.

• Permits for discharges of dredged or fill material into navigable waters. 33 U.S.C. 1344.

• Regulation of artificial islands, installations, and devices on the outer continental shelf. 43 U.S.C. 1333(e).

*Department of Energy*

Federal Energy Regulatory Commission (hydroelectric power, electric transmission, electric supply, facility siting):

•Regulation of interconnection of electric transmission facilities, and regulation of enlargement of electric transmission facilities for wheeling. 16 U.S.C. 824–825K (18 CFR 32).

•Regulation of the development of water power including the licensing of non Federal hydroelectric power projects. Federal Power Act. 16 U.S.C.
825r (18 CFR 4–25, 36, 131, 141).

fice of Conservation and Solar
ications (transportation Industry; public buildings, industrial heating).

Office of Energy Technology (technology development).

Power Marketing Administration (as geographically appropriate).

•Approvals for plans for power plans and major fuel burning facilities:

Federal Energy Admihistration Act of 1974. 15 U.S.C. 761–790h.

Powerplant and Industrial Fuel Use Act of 1978, Pub. L. 95–620, 92 Stat. 3289

*Department of Health, Education, and Welfare*

Public Health Service.

National Institutes of Health (radiation effects).

*Department of Housing and Urban Development (urban areas)*

*Department of the Interior*

Bureau of Indian Affairs:

•Leases of Indian lands. 25 U.S.C. 392–403b, 415 (25 CFR Part 131).

•Leases, permits, easements of public lands. 43 U.S.C. 931c, 931d (43 CFR Part 9)

•Rights-of way over Indian lands. 25 U.S.C. 311 *et seq.* (25 CFR Part 161); 25 U.S.C. 15 (25 CFR Parts 231–233).

Bureau of Land Management (public lands):

•Licenses for synthetic liquid fuel facilities. 30 U.S.C. 323.

•Placer mining claims on lands withdrawn or reserved for power development or power sites. 30 U.S.C. 621.

•Geothermal leases. 30 U.S.C. 1002–1011.

•Rights-of-way (various purposes, e.g., power lines and authorities). *See* 43 CFR Parts 2800, 2811, 2820, 2840, 2850, 2870, 2880, 2890.

•Mineral leasing on the outer continental shelf. 43 U.S.C. 1331–1343.

•Uranium leases (acquired lands). —— U.S.C. ——.

•Solar energy facility siting. —— U.S.C. ——.

•Public works—leases, permits, easements. 43 U.S.C. 931c, 931d (43 CFR Part 9).

Bureau of Mines (mining research).

—Bureau of Reclamation.

• Public works—leases, permits, easements. 43 U.S.C. 931c, 931d (43 CFR Part 9).

Geological Survey (classification of federal lands as to their water power and water storage values).

• Geothermal lease operations. 30 U.S.C. 1023 (30 CFR 270–271).

Fish and Wildlife Service (effects on fish and wildlife resources).

• Public works—leases, permits, easements. 43 U.S.C. 931c, 931d (43 CFR Part 9)

Heritage Conservation and Recreation Service (effects on historic or recreational values).

National Park Service.

• Rights-of way through parks or reservations for power and communications facilities. 16 U.S.C. 5.

*Department of Transportation*

Federal Highway Administration.

• Relocation and accomodation of utility facilities on highway rights-of-way. 23 U.S.C. 109(1), 116, 123 (23 CFR Part 645).

Environmental Protection Agency (pollution control).

*Nuclear Regulatory Commission*

• Licensing for utilization or production facilities for industrial or commercial purposes. 42 U.S.C. 2133 (10 CFR 50).

• Nuclear power reactor operator's licneses. 42 U.S.C. 2137 (10 CFR Part 55).

• Licensing uranium milling operations. 42 U.S.C. 2091 *et seq.* (10 CFR Part 40).

• Licensing and regulating demonstration reactors. 42 U.S.C. 2134, 5842 (10 CFR Part 50).

*Department of Transportation (transport of sources)*

Federal Aviation Administration

*Tennessee Valley Authority (Tennessee Valley Region)*

*Water Resources Council (water resources planning and data)*

River Basin Commissions (as geographically appropriate).

### *B. Petroleum Development, Extraction, Refining, Transport and Use*

*Department of Agriculture*

Forest Service (National Forests and Grasslands).

*Department of Commerce*

National Oceanic and Atmospheric Administration (costal and marine resources—management and protection).

Maritime Administration (port, costal and ocean pollution).

• Merchant vessels. 42 U.S.C. 1101 *et seq.*

• Port operations. 42 U.S.C. 867 (41 Stat. 992).

*Department of Defense*

Army Corps of Engineers.

• Rules governing work or structures in or affecting the navigable waters of the United States. 33 U.S.C. 403.

• Permits for discharges of dredged or fill materials into navigable water. 33 U.S.C. 1344.

• Regulation of artificial islands, installations and devices on the outer continental shelf 43 U.S.C. 1333 (c).

*Department of Energy*

Office of Energy Technology (technology development).

*Department of the Interior*

Bureau of Indian Affairs.

• Rights-of-way over Indian lands 25 U.S.C. 311, *et seq.* (25 CFR Part 161, 171, 172, 183, 184).

• Leases for mining, oil and gas, farming and other uses on federal lands. 25 U.S.C. 393 *et seq.* (25 CFR 171, 172).

Bureau of Land Management (public lands and outer continental shelf).

• Application for patents on phosphate, nitrate, oil and asphaltic mineral deposits 30 U.S.C. 121, 122, 123.

• Oil and gas leases 30 U.S.C. 221.

• Lease of oil and gas deposits located in rights-of way. 30 U.S.C. 301.

• Oil pipeline rights-of-way; leases for oil shale, native asphalt, solid and semi-solid bitumen, and bituminous rock. 30 U.S.C. 241.

Bureau of Mines (environmental effects of oil mining).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey.

• Oil and gas lease operations:

Public domain. 30 U.S.C. 181, *et seq.* (30 CFR 221).

Acquired land. 30 U.S.C. 351, *et seq.* (30 CFR 221).

Outer continental shelf lands. 43 U.S.C. 1331, *et seq.* (30 CFR 250, 251).

Indian lands. 25 U.S.C. 396a, *et seq.* (25 CFR 171, 172, 174, 183, 184).

• Sale and purchase of government royalty on application. 30 U.S.C. 189, 192, 359; 43 U.S.C. 1334 (30 CFR Part 225).

Heritage Conservation and Recreation Service (effects on historical or recreational values).

National Park Service.

• Permits and leases for oil and gas. 16 U.S.C. Ch. 1.

*Department of State*

• Facilities for export/import of petroleum products, coal, minerals, water, sewage permits. Executive Order 11423.

*Department of Transportation (transport and pipeline safety)*

Coast Guard:

• Tank vessel regulation. 46 U.S.C. 391a.

• Ports and waterways safety. 33 U.S.C. 1221.

• Construction and alteration of bridges over navigable waters (for pipelines). 33 U.S.C. 525, 33 U.S.C. 494, 496, 33 U.S.C. 513-14.

• Outer continental shelf structures 43 U.S.C. 1331.

Federal Highway Administration.

• Relocation and accommodation of pipelines on highway rights of way 23 U.S.C. 109(1), 116, 123 (23 CFR Part 645).

Research and Special Programs Administration

Materials Transportation Bureau (pipeline safety).

*Environmental Protection Agency (pollution control)*

*Federal Maritime Commission*

Office of Environmental Analysis (carrier rates or agreements)

*Interstate Commerce Commission (regulation of carriers)*

*C. Natural Gas Development, Production, Transmission, and Use*

*Department of Agriculture*

Forest Service (National Forests and Grasslands).

*Department of Commerce*

National Oceanic and Atmospheric Administration (coastal and marine resources—management and protection).

Maritime Administration:

• Liquid natural gas vessels. 42 U.S.C. 1101, *et seq.*

• Liquid natural gas terminals. 46 U.S.C. 867 (41 Stat 992).

*Department of Defense*

Army Corps of Engineers:

• Rules governing work or structures in or affecting the navigable waters of the United States. 33 U.S.C. 403.

• Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.

• Regulation of artificial islands, installations, and devices on the outer continental shelf. 43 U.S.C. 1333(3).

*Department of Energy*

Federal Energy Regulatory Commission.

• Certificates for natural gas facilities (underground storage fields, LNG facilities, and transmission pipeline facilities); sale, exchange and transportation of gas; abandonment of facilities; and curtailment of natural gas service. Natural Gas Act. 15 U.S.C. 717-717w.

*Department of Housing and Urban Development*

Office of Community Planning and Development (residential and other lands).

*Department of the Interior*

Bureau of Indian Affairs.

• Leases for mining, oil and gas, farming and other uses on federal lands 25 U.S.C. 393 *et seq.* (25 CFR 171, 172).

Bureau of Land Management (public lands).

• Application for patents on phosphate, nitrate, oil and asphaltic mineral deposits 30 U.S.C. 121, 122, 123.

• Oil and Gas leases. 30 U.S.C. 221.

• Lease of oil and gas deposits located in rights of way 30 U.S.C. 301.

• Leasing of oil and gas deposits on the outer continental shelf. 43 U.S.C. 1331-1343.

• Gas pipeline rights-of-way. —— U.S.C. ——.

Bureau of Mines (methane; drainage and subsidence problems. Federal Helium Program).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey:

• Communitization of federal oil and gas leases 30 U.S.C. 181 *et seq.*, 315 *et seq.*

• Oil and gas lease operations:

Public domain. 30 U.S.C. 181, *et seq.* (30 CFR 221).

Acquired lands 30 U.S.C. 351 *et seq.* (30 CFR 221).

Outer continental shelf land. 43 U.S.C. 1331 *et seq.* (30 CFR 250, 251).

Indian lands 25 U.S.C. 396a, *et seq.* (25 CFR 171, 172, 173, 174, 183, 184).

Heritage Conservation and Recreation Service (effects on historical and recreational values).

National Park Service.

• Permits and leases for oil and gas. 16 U.S.C. Ch. 1.

*Department of Transportation (transport and safety)*

Coast Guard:

• Tank vessel regulation. 46 U.S.C. 391a.

• Navigation and waterfront facility regulation. 33 U.S.C. 1221, 1321; 50 U.S.C. 191.

• Construction and alteration of bridges over navigable waters (for pipelines) 33 U.S.C. 525; 33 U.S.C. 494-95; 33 U.S.C. 513-14.

• Outer continental shelf structures. 43 U.S.C. 1331.

Federal Highway Administration.

• Relocation and accommodation of pipelines on highway rights-of-way. 23 U.S.C. 109(1), 116, 123 (23 CFR Part 645).

Federal Railroad Administration (railroad transport).

Research and Special Programs Administration.

Materials Transportation Bureau (pipeline safety).

*ironmental Protection Agency*
*lution control)*

*Interstate Commerce Commission (regulation of carriers)*

### D. Coal and Minerals Development. Mining Conversion. Processing. Transport and Use

*Appalachian Regional Commission (Appalachian region)*

*Department of Agriculture*

Forest Service (National Forests and Grasslands):

- Surface use of public domain lands under U.S. mining laws. 16 U.S.C. 478–555 (36 CFR 252).
- Mineral development on acquired lands for solid (hardrock) minerals. 16 U.S.C. 520 (36 CFR 252). and for phosphate. oil. gas. oil shale. sodium. potassium and sulphur. 30 U.S.C. 352.
- Coal leasing. 30 U.S.C. 201–352.
- Surface coal mining operations. 30 U.S.C. 1272.
- Geothermal resource developments. 30 U.S.C. 1014.

Rural Electrification Administration.

- Financial assistance for purchase of coal mines and mining facilities. 7 U.S.C. 901 *et seq.*

Soil Conservation Service (abandoned ned land: transportation).

*partment of Commerce (technical and economic information)*

*Department of Defense*

Army Corps of Engineers:

- Rules governing work or structures on or affecting navigable waters of the United States. 33 U S C. 403.
- Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or tributary of a navigable water. 33 U.S.C. 407.

*Department of Energy*

Federal Energy Regulatory Commission.

- Approvals for plans for powerplants and major fuel-burning facilities:

Federal Energy Administration Act of 1974. 15 U.S C. 761–790h.

Powerplant and Industrial Fuel Use Act of 1978. Pub. L 95–620. 92 Stat. 3289.

*Department of Housing and Urban Development*

Office of Policy development and Research (subsidence).

*epartment of the Interior*

ureau of Indian Affairs:

- Rights-of-way over Indian lands. 25 U.S.C. 311 *et seq.* (25 CFR Part 161. 171. 172. 177).
- Leases for mining. oil and gas. farming and other uses on federal lands. 25 U.S C. 392 *et seq.* (25 CFR Part 131. 171. 172. 177).

Bureau of Land Management (public lands):

- Patents on coal deposits. 30 U.S.C. 81. 82.
- Patents on lands with reservation of coal. 30 U.S.C. 85.
- Leases and permits for coal lands. 30 U.S.C. 181.
- Permits to take coal for domestic needs. 30 U.S.C. 208.
- Lease of mineral deposits in acquired lands. 30 U.S.C. 352.
- Lease of partial or future interests in mineral deposits. 30 U.S.C. 354.
- Leases and permits for phosphate. potassium, and sodium. 30 U.S.C. 181 *et seq:* 30 U.S.C. 351–359; Reorganization Act of July 16. 1946.
- Leases and permits for sulpher in Louisiana and New Mexico. 30 U.S.C. 181 *et seq:* 30 U.S.C. 351–359: Reclamation Act of July 16. 1946.
- Determination of unpatented mining claims. 30 U.S.C. 527.
- Mining location for source material. 30 U.S.C. 541.
- Conveyance of title to an unpatented mining claim. 30 U.S.C. 701–709.
- Leases. permits and licenses for mining in wild and scenic rivers system. 16 U.S.C. 1280.

Bureau of Mines (mining activities).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey:

- Consolidation of coal leases. 30 U.S C. 202a.
- Coal lease exploration. 30 U.S.C. 201b.
- Exploration and mining operations for leaseable minerals other than coal. 30 U.S.C. 211. 241. 261. 281. (30 CFR 231).

Heritage Conservation and Recreation Service (effects on historical and recreational values).

National Park Service:

- Leases. permits and licenses for mining subject to regulations of Secretary of the Interior on lands involved in Wild and Scenic River Systems. 16 U.S.C. 1280.
- Access permits for mining activity within the National Park System. 16 U.S.C. 1902. 1908 (36 CFR 9).

Office of Minerals Policy and Research Analysis (research).

Office of Surface Mining Reclamation and Enforcement:

- Permits for surface coal mining. 30 U.S C. 1256–1262 (30 CFR Ch. VII).
- Permits for underground coal mining. 30 U.S.C. 1266(b) (30 CFR Ch. VII).

*Department of Labor*

Mine Safety and Health Administration (worker safety).

Occupational and Safety and Health Administration (worker safety in very limited situations).

*Department of Transportation*

Federal Highway Administration (coal haul roads. effects of railroad coal transport on roads and streets).

Federal Railroad Administration (railroad transport).

*Environmental Protection Agency (pollution control)*

*Interstate Commerce Commission (regulation of carriers)*

*Tennessee Valley Authority (Tennessee Valley region)*

## III. Land Use

### A. Land Use Changes. Planning. and Regulation of Land Development

*Department of Agriculture*

Agricultural Stabilization and Conservation Service (agricultural land use programs).

Forest Service (National Forest and Grasslands):

- Special use permits. archaeological permits, leases and easements. 16 U.S.C. 497; 16 U.S.C. 580d. 48 U.S.C. 341 (36 CFR 251). section 261.
- Mineral exploitation of acquired lands. 16 U.S C. 520 (36 CFR 252).
- Easement and road rights-of-way in National Forests and other lands. 16 U.S.C. 533 (36 CFR 212.10).
- Grazing permits. 16 U.S C. 580 (K) and (L) (36 CFR 227.1).
- Geothermal resource developments. 30 U.S.C. 1014.
- Multiple-use sustained-yield units. 16 U.S.C. 528 (36 CFR 223).
- Surface use on public domain lands under U.S. mining laws. 16 U.S.C. 478–551 (36 CFR 252).
- Minerals development on acquired lands:

Solid (hardrock) minerals. 16 U.S.C. 520.

Phosphate oil. gas. oil shale. sodium. potassium and sulphur. 30 U.S.C. 352.

- Coal leasing. 30 U.S C. 201–352.
- Surface coal mining operations. 30 U.S C. 1272.
- Bankhead-Jones Farm Tenant Act. Title III—Administration of national grasslands. 7 U.S.C. 1010–1012 (36 CFR 213.3).
- Claim of privately owned horses and burros. (36 CFR 222).

Economics. Statistics and Cooperatives Service (data: natural resources).

Science and Education Administration (rural and community development).

Soil Conservation Service (watershed protection).

*Department of Defense*

Army Corps of Engineers (flood plains).

Department of the Air Force (land use around airfields).

*Department of Housing and Urban Development*

Office of Interstate Land Sales (land sales).

Office of Community Planning and Development (community development; planning activities).

- Subdivided land sales, registration. Interstate Land Sales Full Disclosure Act. 15 U.S.C. 1701.

*Department of the Interior*

Bureau of Indian Affairs:

- Sale by Secretary of the Interior of land purchased for Indian administrative uses. 25 U.S.C. 293.
- Rights-of-way over Indian lands. 25 U.S.C. 311–328 (25 CFR 161).
- Irrigation lands. 25 U.S.C. 381 (25 CFR 191, 203).
- Leasing for mining, oil and gas, farming and other uses on federal lands. 25 U.S.C. 393 *et seq.* (25 CFR 171, 172).
- Grazing permits (25 CFR 151; 141).

Bureau of Land Management (public lands):

- Disposition of lands in Indian reservations. 30 U.S.C. 85, 87, 88.
- Limitations on entry upon saline lands. 30 U.S.C. 162.
- Securing rights-of-way for pipeline purposes. 30 U.S.C. 185(a).
- Use of surface of public lands withdrawn or reserved for power development or power sites for placer mining. 30 U.S.C. 621.
- Management of outer continental shelf for mineral leasing. 43 U.S.C. 1331–1343.
- Federal Land Policy and Management Act. 43 U.S.C. 1701 *et seq.*
- Grazing permits. Taylor Grazing Act. 43 U.S.C. 315, 315a–r.
- The Act of August 28, 1937. 43 U.S.C. 1181d.
- Mineral leases and permits under the Mineral Leasing Act of 1920, as amended. 30 U.S.C. 181 *et seq.*
- The Acquired Lands Mineral Leasing Act of 1947, as amended. 30 U.S.C. 315–359.
- Permits for underground coal mining. 30 U.S.C. 1266(b).
- Leasing lands to government or non-profit groups. 43 U.S.C. 869.
- Lease of public lands for airports. 49 U.S.C. 211–214 (43 CFR 2640).
- Special land use permits. Federal Land Policy and Management Act of 1976 (43 CFR Part 2920).
- Disposal and use of sand, stone and gravel. 30 U.S.C. 601, 602.

Bureau of Mines (minerals).

—Bureau of Reclamation (public works).

Fish and Wildlife Service (effects on fish and wildlife resources).

- National Wildlife Refuge use permits. 16 U.S.C. 668dd–668ee (50 CFR 24.41).

Geological Survey (land use, geographic hazards, topographic and photographic mapping).

Heritage Conservation and Recreation Service (conservation, national trails).

National Park Service (National Parks):

- Leases, permits and licenses for mining subject to regulations of Secretary of the Interior on lands involved in Wild and Scenic River System. 16 U.S.C. 1200.
- Access permits for mining activity within the National Park System. 16 U.S.C. 1902, 1908 (36 CFR 9).
- Special use permits, archeological permits, grazing permits, leases and easements, rights-of-way. 16 U.S.C. Ch. 1.

Office of Surface Mining Reclamation and Enforcement (surface mining).

*Federal Maritime Commission*

Office of Environmental Analysis (carrier rates and agreements).

*Department of Transportation*

Coast Guard:

- Permits for causeways. 33 U.S.C. 401.
- Bridges over navigable waters—33 U.S.C. 401, 491, 525.
- Approval of plans to alter a bridge. 33 U.S.C. 514.

Federal Aviation Administration (airports, land acquisition, release of airport property from surplus property disposal restrictions, construction or alternation of objects affecting navigable airspace, land use compatability).

Federal Highway Administration:

- Approval of highway projects and programs. 23 U.S.C. 101–158, generally, and 23 U.S.C. 204, 208–210, 212–219.
- Regulation of highway-related land use.

Highway beautification. 23 U.S.C. 131 (23 CFR Part 750)

Junkyard control and acquisition. 23 U.S.C. 136, 315 (23 CFR Part 751).

Landscapes and roadsides development. 23 U.S.C. 131, 315, 319 (23 CFR Part 752).

*Environmental Protection Agency (pollution effects)*

*National Aeronautics and Space Administration (advanced technology, for remote sensing of land use and land cover)*

*National Capitol Planning Commission*

- Approval of land-use plans and construction in National Capitol D.C. Code 5–428, 40 U.S.C. 74a(DC Code 9–304; D.C. Code 8-104; Pub. L. 90-553, Section 4, 40 U.S.C. 122 (D.C. Code 8–115).

*Water Resources Council*

River Basin Commissions (as geographically appropriate)

*B. Public Land Management*

*Department of Agriculture*

Forest Service (National Forests and Grasslands management):

- Special use permits, archaeological permits, leases and easements. 16 U.S.C. 497, 16 U.S.C. 500d, 48 U.S.C. 341 (36 CFR 251), see also section 201.
- Geothermal resource developments. 30 U.S.C. 1014.
- Surface coal mining operations. 30 U.S.C. 1272.
- Coal leasing. 30 U.S.C. 201–352.
- Mining development on acquired lands.

Solid (hardrock) minerals. 16 U.S.C. 520 (36 CFR 252.

Phosphate, oil, gas, oil shale, sodium, potassium and sulphur. 30 U.S.C. 352.

- Easement and road rights-of way in National Forests and other lands. 16 U.S.C. 533 (36 CFR 212.10).
- Grazing permits. 16 U.S.C. 580 (K) and (L) (36 CFR 227.1).
- Multiple use sustained-yield units. 16 U.S.C. 528 (36 CFR 223).
- Bankhead-Jones Farm Tenant Act, Title III—Administration of National Grasslands. 7 U.S.C. 1010–12 (36 CFR 213.3).
- Claim of privately owned horses and burros. 36 CFR 222.

*Department of Defense (Lands Under Department Control)*

Army Corps of Engineers (project recreation lands).

Department of the Air Force (land use around airfields).

*Department of the Interior*

Bureau of Indian Affairs:

- Sale by Secretary of the Interior of land purchased for Indian administrative uses. 25 U.S.C. 293.
- Leases, permits and easements on public land under the jurisdiction of BIA. 43 U.S.C. 931c, 931d (43 CFR Part 9).
- Irrigation lands. 25 U.S.C. 381 (25 CFR 203.4).

- Grazing permits 25 CFR 151.

Bureau of Land Management:

- Placer mining claims on lands withdrawn or reserved for power development of ower sites. 30 U.S.C. 621.
- Federal Land Policy and Management Act. 433 U.S.C. 1701, *et seq.*
- Grazing permits. Taylor Grazing Act. 43 U.S.C. 315, 315a–315r.
- Act of August 28, 1937. 43 U.S.C. 1181d.
- Antiquities permits. —— U.S.C. ———.
- Special Recreation permits. —— U.S.C. ———.
- Mineral leasing on the Outer Continental Shelf. 43 U.S.C. 1331–1343.
- Leases, permits and licenses for mining in Wild and Scenic Rivers Areas. 16 U.S.C. 1280.
- Leasing lands to government or non-profit groups. 43 U.S.C. 869.
- Lease of public lands for airports. 49 U.S.C. 211–214 (43 CFR 2640).
- Rights-of-way (various purposes (e.g., roads, railroads power lines, irrigation, pipelines, mineral leasing) and authorities). *See* 43 CFR Parts 2800, 2811, 2820, 2840, 2850, 2870, 2860, 2890.
- Special land use permits. Federal Land Policy and Management Act of 78 (43 CFR Part 2920).
- Disposal and use of sand, stone and gravel. 30 U.S.C. 601, 602.

Bureau of Mines (mineral land assessment).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey:

- Outer Continental Shelf. 43 U.S.C. 1331–1343.
- Onshore oil, gas, mining. 30 U.S.C. 181 *et seq.*
- Onshore oil, gas, mining on Indian lands. 25 U.S.C. 396, 396a–298, 35 Stat. 812.
- Geothermal. 30 U.S.C. 1023.

Heritage Conservation and Recreation Service (conservation, fund state programs).

National Park Service (public lands):

- Leases, permits and licenses for mining subject to regulations of Secretary of the Interior on lands involved in Wild and Scenic River System. 16 U.S.C. 1280.
- Access permits for mining activity within the National Park System. 16 U.S.C. 1902, 1908 (36 CFR 9).
- Special use permits, archeological permits, grazing permits, leases and easements, rights-of-way. 16 U.S.C. Ch. 1.

Office of Surface Mining Reclamation and Enforcement:

- Permits for surface coal mining. 30 U.S.C. 1256–1282.
- Permits for underground coal mining. 30 U.S.C. 1266(b).

*Department of Transportation*

- Transportation programs with measures to protect land traversed (particularly parks, recreation areas and historic sites). Department of Transportation Act as amended. 49 U.S.C. 1651–1659.

Federal Highway Administration (construction and management of National Park Service roads and forest highways):

- Approval of projects for Indian reservation roads and bridges. 23 U.S.C. 208.
- Construction of public lands highways. 23 U.S.C. 209.
- Approval of projects for public lands development roads and trails. 23 U.S.C. 214.

*General Services Administration (public buildings management)*

Federal Property Resources Service (excess land disposal).

*National Aeronautics and Space Administration (advanced technology remote sensing of land use and land cover)*

*Tennessee Valley Authority (project lands)*

### *C. Land Use in Coastal Areas*

*Department of Agriculture*

Forest Service (National Forest and Grasslands).

Soil Conservation Service (soil stability, hydrology).

*Department of Commerce.*

Maritime Administration (ports).

National Oceanic and Atomospheric Administration (coastal and marine resources and protection):

- Permits for activities in designated marine sanctuaries. 16 U.S.C. 143 *et seq.* (15 CFF 922).
- Approval and funding of state coastal management programs. 16 U.S.C. 1451 *et seq.* (15 CFR 923, 930).
- Protection of endangered species and critical habitats. 16 U.S.C. 1531 *et seq.* (50 CFR 222).
- Establishment of estuarine santuaries. 16 U.S.C. 1461 (15 CFR 921).

*Department of Defense*

Army Corps of Engineers (beaches, dredge and fill permits, Refuse Act permits):

- Rules governing work or structures in or affecting navigable waters of the United States 33 U.S.C. 401, 403 and 419.
- Authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or tributary of a navigable water 33 U.S.C. 407.
- River and harbor improvement projects. 33 U.S.C. 541.
- Permits for private projects to improve navigable waters. 33 U.S.C. 565.
- Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Permits for transportation of dredged materials for dumping into ocean waters. 33 U.S.C. 1413.

*Department of Housing and Urban Development (development in coastal areas)*

*Department of the Interior*

Bureau or Indian Affairs (Indian lands).

Bureau or Land Management (public lands):

- Cooperation with states in developing coastal zone plans. 86 Stat. 1280.
- Limitations on entry upon saline lands. 30 U.S.C. 162.
- Mineral leasing on the outer continental shelf. 43 U.S.C. 1331–1343.

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey (estuarine areas):

- Permits for geological and geophysical exploration on outer continental shelf. 43 U.S.C. 1340 (30 CFR 251).
- Permits for exploration and development activities on federal oil and gas leases on the outer continental shelf 43 U.S.C. 1331 *et seq.* (30 CFR 250).

Heritage Conservation and Recreation Service (historical and recreational values).

National Park Service (barrier island ecology and coastal processes).

*Department of Transportation*

Coast Guard (bridges, navigation and deepwater ports):

- Bridges over navigable waters—permits 33 U.S.C. 525.
- Approval of plans to alter a bridge. 33 U.S.C. 514.
- Permits for causeways. 33 U.S.C. 401.
- Waterfront facilities. 33 U.S.C. 1221, 1321.
- Deepwater port regulation. 33 U.S.C. 1503–1524.
- Vessel operating requirements. —— U.S.C. ———.
- Licensing of persons to engage in the ownership, construction or operation of a deepwater port. 33 U.S.C. 1503–1520.

Environmental Protection Agency (pollution effects):

- Permits for ocean discharges. 33 U.S.C. 1343.
- Permits for disposals of sewage sludge. 33 U.S.C. 1345.

• Oil spills prevention, containment, and countermeasure plans (prepared by facility owner/operator). Sections 311, 501, 33 U.S.C. 1321, 1361 (40 CFR 112.7).

Federal Maritime Commission, Office of Environmental Analysis (terminal agreements).

National Aeronautics and Space Administration (advanced technology for remote sensing of land use and land cover).

*D. Protection of Environmentally Critical Areas—*

Floodplains, Wetlands, Beaches and Dunes, Unstable Soils, Steep Slopes, Aquifer Recharge Areas, Tundra, Etc.

*Department of Agriculture*

• Watershed Protection and Flood Prevention Act. 16 U.S.C. 1001–1009 (7 CFR Parts 15, 23, 600).

Agricultural Stabilization and Conservation Service (commodity and land use programs; Water Bank).

Forest Service (National Forest lands).

Science and Education Administration (soil and water conservation program).

Soil Conservation Service (watershed protection and flood control; soil and water conservation).

*Department of Commerce*

National Oceanic and Atmospheric Administration (coastal and marine resources, management and protection):

• Protection of endangered species and critical habitats. 16 U.S.C. 1531, *et seq.* (50 CFR 222)

• Permits for activities in designated marine sanctuaries. 16 U.S.C. 1431, *et seq.* (15 CFR 922).

• Establishment of estuarine sanctuaries. 16 U.S.C. 1461 (15 CFR 921).

• Approval and funding of state coastal management programs. 16 U.S.C. 1451 *et seq.* (15 CFR 923; 930).

*Department of Defense*

Army Corps of Engineers:

• Permits for discharge of dredged or fill materials into navigable waters. 33 U.S.C. 1344.

• Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401, 403, 419.

*Department of Health, Education, and Welfare*

Public Health Service.

Center for Disease Control (health issues).

*Department of Housing and Urban Development*

Office of Community Planning and Development (urban and floodplain areas).

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

Bureau of Land Managment:

• Limitations on entry upon saline lands. 30 U.S.C. 182.

• Management of areas of critical environmental concern. 43 U.S.C. 1701.

Bureau of Reclamation (public works).

Fish and Wildlife Service (protection of fish and wildlife resource values).

Geological Survey (topography, geology, hydrology).

Heritage Conservation and Recreation Service (historical and recreational values).

National Park Service (National Park lands).

Office of Surface Mining Reclamation and Enforcement (designation of areas unsuitable for surface coal mining).

Office of Water Research and Technology (water resource planning).

*Department of Transportation*

Coast Guard.

• Establishment of port access routes. 33 U.S.C. 1221.

Federal Highway Administration:

• Approval of federal-aid highway projects. 23 U.S.C. 101–156, generally.

• Approval of highway bridge replacement and rehabilitation. 23 U.S.C. 144 (23 CFR Part 650).

*Environmental Protection Agency (pollution effects)*

• Temporary underground injection permits. Safe Drinking Water Act. 42 U.S.C. 300h(C)(1).

*Water Resources Council (coordination of floodplain and wetland initiatives)*

River Basin Commissions (as geographically appropriate).

*E. Community Development*

*Advisory Council on Historic Preservation (historic preservation)*

*Department of Agriculture*

Science and Education Administration (rural and community development program).

Soil Conservation Service (soil survery).

*Department of Commerce*

Economic Development Administration (designated areas).

*Department of Health, Education, and Welfare*

Public Health Service.

Center for Disease Control (health).

Office of Human Development Services (problems of handicapped, aged, children and Native Americans).

*Department of Housing and Urban Development*

Office of Community Planning and Development (community development; effects on low income populations; economic revitalization in distressed areas; density and congestion mitigation; rehabilitation and urban homesteading).

*Department of the Interior*

Bureau of Indian Affairs (Indian Lands).

Geological Survey (flood, seismic, and geologic hazards).

Heritage Conservation and Recreation Service (landmarks, archeological remains, outdoor recreation, historic preservation).

*Department of Transportation*

Federal Aviation Administration (airports).

Federal Highway Administration:

• Relocation assistance in connection with highway projects. 42 U.S.C. 4601 *et seq.* (23 CFR Part 740, 49 CFR Part 25).

• Approval of economic growth center development highways. 23 U.S.C. 143.

Urban Mass Transportation Administration.

• Urban Mass Transportation Act. 49 U.S.C. 1610.

*Environmental Protection Agency (pollution control)*

*General Services Administration (building design and construction)*

*National Capitol Planning Commission (Washington, D.C. area)*

• Approval of Land use plans and construction in the National Capitol. D.C. Code 5–428, 40 U.S.C. 74a (D.C. Code 9–304); D.C. Code 8–104; Pub. L. 90–553, section 4; 40 U.S.C. 122 (D.C. Code 8–115).

*National Endowment for the Arts (artistic values)*

*F. Historic, Architectural, and Archeological Preservation*

*Advisory Council on Historic Preservation (historic preservation)*

*Department of Agriculture*

Forest Service (National Forest and Grasslands).

*Department of Housing and Urban Development (in urban areas)*

*Department of the Interior*

• Permits to examine ruins, excavations and gathering of objects on land under jurisdiction of Interior, Agriculture and Army. 16 U.S.C. 432.

Bureau of Indian Affairs (Indian lands).

• Preservation of antiquities. 16 U.S.C. [illegible]2 (25 CFR 132).

Bureau of Land Management (public lands).

• Antiquities search and collection permit. Antiquities Act. 16 U.S.C. 432 (43 CFR 3).

Heritage Conservation and Recreation Service (historic and cultural landmarks):

• Antiquities Act of 1906. 16 U.S.C. 431–433 (43 CFR 3). National Historic Preservation Act of 1966. 16 U.S.C. 470 *et seq.*

• Archaeological and Historic Preservation Act. 16 U.S.C. 469.

National Park Service (National Park lands).

*Department of Transportation*

• Approval of transportation programs or projects that require the use of an historic site 42 U.S.C. 1653(f).

Federal Highway Administration.

• Approval of transportation programs or projects that require the use of an historic site 42 U.S.C. 138.

• Archeological and paleontological salvage on federal and federal-aid highway projects 23 U.S.C. 305 (23 CFR Part 765).

*General Services Administration*

Public Buildings Service (in urban areas).

*National Capitol Planning Commission*

• Approval of land use plans and construction in National Capitol. D.C. Code 5–428. 40 U.S.C. 74a (D C. Code 9–304): D.C. Code 8–104: Pub. L. 90–553. section 3: 40 U.S.C. 122 (D.C. Code 8–115).

*National Endowment for the Arts*

*G. Outdoor Recreation*

*Department of Agriculture*

Forest Service (National Forest land).

Soil Conservation Service (watershed protection).

*Department of Defense*

Army Corps of Engineers (recreation areas on DOD lands).

*Department of Health. Education. and Welfare*

Public Health Service.

Center for Disease Control (Health).

*Department of Housing and Urban Development (urban areas)*

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands).

Fish and Wildlife Service (effects on fish and wildlife resources).

Heritage Conservation and Recreation Service.

• Land and Water Conservation Act. 16 U S.C. 460(L)4–(L)11–(L)22.

National Park Service (National park lands).

*Department of Transportation*

Coast Guard.

• Recreational boating regulation. 46 U.S.C. 1451.

Federal Highway Administration:

• Preservation of parklands. 23 U.S.C. 138.

• Access highways to public recreation areas on lakes. 23 U.S.C. 155.

*Environmental Protection Agency (pollution control)*

*Water Resources Council (water and related land resources)*

River Basin Commission (as geographically appropriate)

IV. Natural Resource Management

*A. Weather Modification*

*Department of Agriculture*

Forest Service (National Forests and Grasslands).

Soil Conservation Service (snow survey).

World Food and Agricultural Outlook and Situation Board (data relating to commodities).

*Department of Commerce*

National Oceanic and Atmospheric Administration (research and development: reports on private activities).

*Department of Defense*

Department of the Air Force (fog dissipation).

*Department of the Interior*

Bureau of Reclamation (water resources research).

National Park Service (public lands).

*B. Waterway Regulation and Stream Modification*

*Department of Agriculture*

Agricultural Stabilization and Conservation Service (resource conservation: Water Bank).

Forest Service (National Forests and Grasslands).

Science and Education Administration (soil and water conservation).

Soil Conservation Service (watershed protection).

*Department of Commerce*

Maritime Administration (merchant vessels. barges and inland vessels).

*Department of Defense*

Army Corps of Engineers:

• Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401. 403. and 419.

• Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (Public lands).

Bureau of Reclamation (public works).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey (hydrology).

National Park Service (National Parks).

*Department of Transportation*

Coast Guard (vessels. bridge. port. and waterway safety: navigation aids):

• Deepwater port regulation. 33 U.S C. 1503–1524.

• Tank vessel regulation. 46 U.S.C. 391a.

• Ports and waterways safety. 33 U.S.C. 1221.

• Construction and alterations on bridges and causeways over navigable waters. 33 U.S.C. 401. 491. 525: 33 U.S.C. 494–95: 33 U.S C. 513–14).

Federal Highway Administration:

• Approval of federal-aid highway and bridge projects involving navigable waters and channel changes. 23 U.S.C. 144 (23 CFR Part 650)

• Approval of toll bridge and ferry projects. 23 U.S.C. 129.

*Environmental Protection Agency (pollution control)*

*Federal Maritime Commission*

Office of Environmental Analysis (approval of terminal agreements).

*Water Resources Council*

• Water Resources Planning Act. 42 U.S.C. 1962 (18 CFR 701–706: 33 CFR 232).

River Basin Commissions (as geographically appropriate).

*C. Soil and Plant Conservation and Hydrology*

*Department of Agriculture*

Agricultural Stabilization and Education Service (soil conservation).

Farmers Home Administration (soil erosion).

Forest Service (National Forest lands).

Science and Education Administration (water and soil conservation).

Soil Conservation Service (soil and watershed conservation).

• Grazing Permits. 16 U.S.C. 580 (K) and (L) (36 CFR 227.1).

• Multiple use sustained-yield units. 16 U.S.C. 528 (36 CFR 223).

• Bankhead-Jones Farm Tenant Act, Title III—Administration of National Grasslands. 7 U.S.C. 1010–1012 (36 CFR 213.3).

*Department of Commerce*

National Oceanic and Atmospheric Administration (coastal and marine resources-management and protection).

*Department of Defense*

Army Corps of Engineers (dredging, aquatic plants).

*Department of the Interior*

Bureau of Indian Affairs (Indian lands):

• Irrigation lands. 25 U.S.C. 381 (25 CFR 203.4).

• Timber cutting permits. 25 CFR 141.19.

• Grazing permits. 25 CFR 151.

Bureau of Land Management (public lands).

• Timber permits for free use. 30 U.S.C. 601 *et seq.*, 189; 43 U.S.C. 315, 1201; 48 U.S.C. 423 (43 CFR Part 5010).

Bureau of Mines (hydraulic effects of mining).

Bureau of Reclamation (public works).

Fish and Wildlife Service (effects on fish and wildlife resources).

• Endangered plants—permit. 50 CFR 17.62.

Geological Survey (geology).

National Park Service (National park lands).

• Special use permits, grazing permits, permits to collect soil, rock, water, and plant specimens. 16 U.S.C. Ch. 1, 3.

*Department of Transportation*

Federal Highway Administration (erosion control in highway projects).

*Environmental Protection Agency (pollution control)*

*National Aeronautics and Space Administration (advanced technology for remote sensing of land covers)*

*Water Resources Council (floodplain and wetland initiatives)*

River Basin Commissions (as geographically appropriate).

*D. Fish and Wildlife*

*Department of Agriculture*

Animal and Plant Health Inspection Service (importation of wildlife and birds; endangered species enforcement).

Forest Service (National Forests and Grasslands).

•Claim of privately owned horses and burros. 36 CFR 222.

Soil Conservation Service (habitat, fish ponds, aquaculture).

*Department of Commerce*

National Oceanic and Atmospheric Administration (coastal and marine resources management and protection):

•Permit for importing marine mammals or products thereof. 16 U.S.C. 1371, 73, 74 (50 CFR 216).

•Scientific research and public display of marine mammals. 50 CFR 18; 50 CFR 216.31, 220.

•Control of fishing by foreign and domestic vessels. 16 U.S.C. 1801, *et seq.* (50 CFR Ch. VI).

•Fish and Wildlife Coordination Act, 16 U.S.C. 1361, *et seq.*

•Permits for activities in designated marine sanctuaries. 16 U.S.C. 1431, *et seq.* (15 CFR 922).

•Approval and funding of state coastal management programs. 16 U.S.C. 1451, *et seq* (15 CFR 923, 930).

•Protection of endangered species and critical habitats. 16 U.S.C. 1531, *et seq.* (50 CFR 222).

•Protection of marine mammals. 16 U.S.C. 1361, *et seq* (50 CFR 216).

•Establishment of estuarian sanctuaries. 16 U.S.C. 1461 (15 CFR 921).

•Trustee of natural resources. 43 U.S.C. 1813 (E.O. 12123).

•Scientific, propagation or survival of marine reptile—permits. 50 CFR 227.72.

National Marine Fisheries Service (endangered species).

*Department of Defense*

Department of the Air Force (bird-aircraft strike hazard reduction).

*Department of the Interior*

Bureau of Indian Affairs (off-reservation treaty fishing).

Bureau of Land Management (wild horses and burros; public lands).

Fish and Wildlife Service (endangered species; effects on fish and wildlife):

•Bald and golden eagle protection—permits (takings for scientific, agricultural, other uses). 16 U.S.C. 668–668d.

•Permits for endangered species export and import. 16 U.S.C. 1538(d).

•Permits for scientific research involving endangered species. 16 U.S.C. 1539.

•Mitigation/compensation for harm to endangered or threatened species or critical habitat. 16 U.S.C. 1539.

•Permits for taxidermy on migratory birds, nests, or eggs for commercial uses. 16 U.S.C. 704.

•Fish and Wildlife Coordination Act, 16 U.S.C. 661 *et seq* (43 CFR Part 17).

•Anadromous Fish Conservation Act, 16 U.S.C. 755 *et seq.*

Heritage Conservation and Recreation Service (outdoor recreation).

National Park Service:

•Permits for collecting animal specimens from National Park System areas. 16 U.S.C. Ch. 1, 3.

•Licenses and permits for sport or commercial fishing in certain National Park System areas. 16 U.S.C. Ch. 1, 3.

•Disposition of surplus animals from National Park System areas. 16 U.S.C. Ch. 1, 3.

*Department of Health, Education, and Welfare*

Public Health Service (health).

Food and Drug Administration (contamination of fish and shellfish with toxics).

*Department of Transportation*

Federal Highway Administration (highway construction).

*Environmental Protection Agency (effects of water pollution)*

*Department of State (international issues)*

*E. Renewable Resource Development, Production, Management, Harvest, Transport and Use*

*Department of Agriculture*

Economic Statistical Cooperation Service (data).

Forest Service (timber sale, free use and other timber management activities in National Forests and Grasslands).

Science and Education Administration (forest and range management).

Soil Conservation Service (watershed protection; soil conservation).

*Department of Commerce*

National Oceanic and Atmoshperic Administration (coastal and marine resources management and development).

*Department of Defense*

Army Corps of Engineers (hydro).

*Department of Energy (hydroelectric power, Office of Conservation and Solar Applications).*

Federal Energy Regulatory Commission.

• Regulation of development of water resources. Federal Power Act. 16 U.S.C. 791–825r (18 CFR 4–25, 36, 131, 141).

*Department of Housing and Urban Development (building materials)*

*Department of the Interior*

Bureau of Indian Affairs (Indian lands).

• Leases of Indian lands. 25 U.S.C. 392–403b, 415, (25 CFR Parts 131, 141–

144, 151–153, 231–233). 25 U.S.C. 311 *eq. (25 CFR Part 161).*

• Rights-of-way over Indian lands. 141, 142, 144, 151–153, 231–233.

Bureau of Land Management (public lands).

• Federal Land Policy and Management Act. 43 U.S.C. 1701 *et seq.*

• Grazing permits. Taylor Grazing Act. 43 U.S.C. 315, 315a–4.

• The Act of August 28, 1937. 43 U.S.C. 1181d.

Bureau of Reclamation (public works).

Fish and Wildlife Service (effects on fish and wildlife resources).

Heritage Conservation and Recreation Service (effects on historical and recreational values).

National Park Service (National Park lands).

• Permits for sport fishing, hunting and grazing. 16 U.S.C. Ch. 1, 3.

*Department of Transportation*

Federal Highway Administration (logging haul roads, access roads).

*Environmental Protection Agency (pollution control)*

*Federal Maritime Commission*

Office of Environmental Analysis (carrier rates).

*rstate Commerce Commission ight rates)*

*F. Energy and Natural Resources Conservation*

*Department of Agriculture*

Agricultural Stabilization and Conservation Service (resource conservation).

Forest Service (National Forests and Grasslands).

Science and Education Administration (soil and water conservation; forest and range management).

Soil Conservation Service (soil and water conservation).

*Department of Energy*

• Energy Conservation Standards for New Buildings Act. 42 U.S.C. 6834.

Federal Energy Regulatory Commission (hydroelectric power and natural gas facilities).

*Department of Commerce*

National Bureau of Standards (energy efficiency).

National Oceanic and Atmospheric Administration (coastal and marine resources—management and protection).

*rtment of Housing and Urban elopment*

Office of Housing (previously FHA) (housing standards).

Office of Policy Development and Research (energy, building technology and standards research).

*Department of the Interior*

Bureau of Indian Affairs (Indian resources).

Bureau of Land Management (public lands).

Bureau of Mines (land reclamation; recycling; and processing and use of materials).

Bureau of Reclamation (water projects).

Geological Survey (oil and gas storage).

• Geothermal lease operations. 30 U.S.C. 1023 (30 CFR 270).

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## Appendix L: Federal Legislation on Land and Natural Resources

### Summary of Main Legislation:

### PL 42, Chapter 152: Mining Law of 1872:

An Act to promote the Development of the mining Resources of the United States.

### PL 44, Chapter 107: Desert Land Act of 1877:

An act to provide for the sale of desert lands in certain States and Territories.

### PL 53, Chapter 301: Carey Act of 1894:

(Sec. 4) That to aid the public land States in the reclamation of the desert lands therein, and the settlement, cultivation and sale thereof in small tracts to actual settlers, the Secretary of the Interior with the approval of the President, be, and hereby is, authorized and empowered, upon proper application of the State in which there may be situated desert lands as defined by the Act entitled "An Act to provide for the sale of desert land in certain States and Territories," approved March /3, 1877/, and the Act amendatory thereof, approved March /3, 1891/, binding the United States to donate, grant and patent to the State free of cost for survey or price such desert lands, not exceeding one million acres in each State, as the State may cause to be irrigated, reclaimed, occupied, and not less than twenty acres of each /160/ acre tract cultivated by actual settlers, within ten years next after the passage of this Act, as thoroughly as is required of citizens who may enter under the said desert land law.

### PL 57-161: Reclamation Act of 1902:

An Act Appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands.

### PL 61-435: Weeks Act of 1911:

An Act to enable any State to cooperate with any other State or States, or with the United States, for the protection of the watersheds of navigable streams, and to approint a commission for the acquisition of lands for the purpose of conserving the navigability of navigable rivers.

PL 64-290: Stock-Raising Homestead Act of 1916:

An Act to provide for stock-raising homesteads, and for other purposes.

. . . it shall be lawful for any person qualified to make entry under the homestead laws of the United States to make a stock-raising homestead entry for not exceeding /640/ acres of unappropriated unreserved public land in reasonable compact form: *Provided, however,* That the land so entered shall theretofore have been designated by the Secretary of the Interior as "stock-raising lands."

PL 66-146: Mineral Leasing Act of 1920:

An Act to promote the mining of coal, phosphate, oil, oil shale, gas, and sodium on the public domain.

PL 69-386: Recreation and Public Purposes Act of 1926:

An Act to authorize acquisition or use of public lands by States, counties, or municipalities for recreational purposes.

PL 73-121: Fish and Wildlife Coordination Act of 1934:

To promote the conservation of wild life, fish, and game, and for other purposes.

PL 73-482: Taylor Grazing Act of 1934:

To stop injury to the public grazing lands by preventing overgrazing and soil deterioration, to provide for their orderly use, improvement, and development, to stabilize the livestock industry dependent upon the public range, and for other purposes.

PL 74-46: Soil Conservation Act

To provide for the protection of land resources against soil erosion, and for other purposes.

--and amendments of 1936: PL 74-461: Soil Conservation and Domestic Allotment Act of 1935:

To promote the conservation and profitable use of agricultural land resources by temporary Federal aid to farmers and by providing for a permanent policy of Federal aid to States for such purposes.

PL 83-566: Watershed Protection and Flood Prevention Act of 1954:

An Act to authorize the Secretary of Agriculture to cooperate with States and local agencies in the planning and carrying out of works of improvment for soil conservation, and for other purposes.

PL 83-585: Multiple Mineral Development Act of 1954:

To amend the mineral leasing laws and the mining laws to provide for multiple mineral development of the same tracts of the public lands, and for other purposes.

PL 84-1021: Great Plains Conservation Program of 1955:

An Act to amend the Soil Conservation and Domestic Allotment Act and the Agricultural Adjustment Act of 1938 to provide for a Great Plains conservation program.

--amended by PL 96-263 in 1980.

PL 87-703: Food and Agriculture Act of 1962:

An Act to improve and protect farm income, to reduce costs of farm programs to the Federal Government, to reduce the Federal Government's excessive stocks of agricultural commodities, to maintain reasonable and stable prices of agricultural commodities and products to consumers, to provide adequate supplies of agricultural commodities for domestic and foreign needs, to conserve natural resources, and for other purposes.

PL 88-206: Clean Air Act of 1963:

(1) to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population;
(2) to initiate and accelerate a national research and development program to achieve the prevention and control of air pollution;
(3) to provide technical and financial assistance to State and local governments in connection with the development and execution of their air pollution prevention and control programs; and
(4) to encourage and assist the development and operation of regional air pollution control programs.

--and Clean Air Act Amendments of 1977: PL 95-05.

PL 88-577: Wilderness Act of 1964:

An Act to establish a National Wilderness Preservation System for the permanent good of the whole people, and for other purposes.

PL 88-578: Land and Water Conservation Fund Act of 1965:

An Act to establish a land and water conservation fund to assist the States and Federal agencies in meeting present and future outdoor recreation demands and needs of the American people, and for other purposes.

--and amendment: PL 95-42 (1977).

PL 89-80: Water Resources Planning Act of 1965:

An Act to provide for the optimum development of the Nation's natural resources through the coordinated planning of water and related land resources, through the establishment of a water resources council and river basin commissions, and by providing financial assistance to the States in order to increase State participation in such planning.

PL 89-560: Community Planning and Resource Development: Soil Surveys of 1966:

An Act to provide that the Secretary of Agriculture shall conduct the soil survey program of the United States Department of Agriculture so as to make available soil surveys needed by States and other public agencies, including community development districts, for guidance in community planning and resource development, and for other purposes.

PL 90-542: Wild and Scenic Rivers Act of 1968:

It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. The Congress declares that the established national policy of dam and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes.

--and amendment: PL 94-486 (1976).

PL 90-583: Noxious Plant Control Act of 1968:

To provide for the control of noxious plants on land under the control or jurisdiction of the Federal Government.

PL 91-190: National Environmental Policy Act of 1969:

To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

PL 91-559: Water Bank Act of 1970:

An Act to provide for conserving surface waters; to preserve and improve habitat for migratory waterfowl and other wildlife resources; to reduce runoff, soil and wind erosion, and contribute to flood control; and for other purposes.

--amended by PL 96-182 (1980).

PL 91-631: Mining and Minerals Policy Act of 1970:

The Congress declares that it is the continuing policy of the Federal Government in the national interest to foster and encourage private enterprise in (1) the development of economically sound and stable domestic mining, minerals, metals and mineral reclamation industries, (2) the orderly and economic development of domestic mineral resources, reserves, and reclamation of metals and minerals to help assure satisfaction of industrial, security and environmental needs, (3) mining, mineral, and metallurgical research, including the use and recycling of scrap to promote the wise and efficient use of our natural and reclaimable mineral resources, and (4) the study and development of methods for the disposal, control, and reclamation of mineral waste products, and the reclamation of mined land, so as to lessen any adverse impact of mineral extraction and processing upon the physical environment that may result from mining or mineral activities.

PL 92-195: Wild Free-Roaming Horses and Burros Act of 1971:

It is the policy of Congress that wild free-roaming horses and burros shall be protected from capture, branding, harassment, or death; and to accomplish this they are to be considered in the area where presently found, as an integral part of the natural system of the public lands.

PL 92-516: Federal Insecticide, Fungicide and Rodenticide Act of 1971:

Registration and regulation of insecticides, fungicides, and rodenticides.

--amended by PL 95-396 (1978).

PL 93-205: Endangered Species Act of 1973:

To provide for the conservation of endangered and threatened species of fish, wildlife, and plants, and for other purposes.

PL 93-320: Colorado River Basin Salinity Control Act of 1974:

An Act to authorize the construction, operation, and maintenance of certain works in the Colorado River Basin to control the salinity of water delivered to users in the United States and Mexico.

PL 93-378: Forest and Rangeland Renewable Resources Planning Act of 1974 directs the Secretary of Agriculture to prepare each tenth year a Renewable Resources Assessment.

PL 94-579: Federal Land Policy and Management Act of 1976:

The Congress declares that it is the policy of the United States that:
(1) the public lands be retained in Federal ownership, unless as a result of the land use planning procedure provided for in this Act, it is determined that disposal of a particular parcel will serve the national interest;
(2) the national interest will be best realized if the public lands and their resources are periodically and systematically inventories and their present and future use is projected through a land use planning process coordinated with other Federal and State planning efforts;
(3) public lands not previously designated for any specific use and all existing classifications of public lands that were effected by executive action or statute before the date of enactment of this Act be reviewed in accordance with the provisions of this Act;
(4) the Congress exercise its constitutional authority to withdraw or otherwide designate or dedicate Federal lands for specified purposes and that Congress delineate the extent to which the Executive may withdraw lands without legislative action;
(5) in administering public land statutes and exercising discretionary authority granted by them, the Secretary be required to establish comprehensive rules and regulations after considering the views of the general public; and to structure adjudication procedures to assure adequate third party participation, objective administrative review of initial decisions, and expeditious decisionmaking;
(6) judicial review of public land adjudication decisions be provided by law;
(7) goals and objectives be established by law as guidelines for public land use planning, and that management be on the basis of multiple use and sustained yield unless otherwise specified by law;
(8) the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecologica, environmental, air and atmosphere, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use;
(9) the United States receive fair market value of the use of the public lands and their resources unless otherwise provided for by statute;
(10) uniform procedures for any disposal of public land, acquisition of non-Federal land for public purposes, and the exchange of such lands be established by statute, requiring each disposal, acquisition, and exchange to be consistent with the prescribed mission of the department or agency involved, and reserving to the Congress review of disposals in excess of a specified acreage;

(11) regulations and plans for the protection of public land areas of critical environmental concern be promptly developed;
(12) the public lands be managed in a manner which recognizes the Nation's need for domestic sources of minerals, food, timber, and fiber from the public lands including implementation of the Mining and Minerals Policy Act of 1970 (84 Stat. 1876, 30 U.S.C. 21a) as it pertains to the public lands; and
(13) the Federal Government should, on a basis equitable to both the Federal and local taxpayer, provide for payments to compensate States and local governments for burdens created as a result of the immunity of Federal lands from State and local taxation.

PL 94-580: Resource Conservation and Recovery Act of 1976:

To provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials and for the safe disposal of discarded materials, and to regulate the management of hazardous waste.

PL 95-87: Surface Mining Act of 1977:

It is the purpose of this Act to:
--establish a nationwide program to protect society and the environment from the adverse effects of surface coal mining operations;
assure that the rights of surface landowners and other persons with a legal interest in the land or appurtenances thereto are fully protected from such operations;
--assure that surface mining operations are not conducted where reclamation as required by this Act is not feasible;
--assure that surface coal mining operations are so conducted as to protect the environment;
--assure that adequate procedures are undertaken to reclaim surface areas as contemporaneously as possible with the surface coal mining operations; . . .
--assist the States in developing and implementing a program to achieve the purposes of this Act;
--promote the reclamation of mined areas left without adequate reclamation prior to the enactment of this Act and which continue, in their unreclaimed condition, to substantially degrade the quality of the environment, prevent or damage the beneficial use of land or water resources, or endanger the health or safety of the public;
--assure that appropriate procedures are provided for the public participation in the development, revision, and enforcement of regulations, standards, reclamation plans, or programs established by the Secretary or any State under this Act; . . .

PL 95-113: Food and Agriculture Act of 1977:

The Secretary of Agriculture, in formulating the national program, shall [consider] (A) the need to control erosion and sedimentation from agricultural land and to conserve the water resources on such land, (b) the need to control pollution from animal wastes, (C) the need to facilitate sound resources management systems through soil and water conservation, (D) the need to encourage voluntary compliance by agricultural producers with Federal and State requirements to solve point and nonpoint sources of pollution, (E) national priorities reflected in the National Environmental Policy Act of 1969 and other congressional and administrative actions, (F) the degree to which the measures contribute to the national objective of assuring a continuous supply of food and fiber necessary for the maintenance of a strong and healthy people and economy, and (G) the type of conservation measures needed to improve water quality in rural America.

PL 95-192: Soil and Water Resource Conservation Act of 1977:

An Act to provide for furthering the conservation, protection, and enhancement of the Nation's soil, water, and related resources for sustained use, and for other purposes.

PL 95-217: Clean Water Act of 1977:

The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In order to achieve this objective it is hereby declared that, consistent with the provisions of this Act--
(1) it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985;
(2) it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983;
(3) it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited;
(4) it is the national policy that Federal financial assistance be provided to construct publicly owned waste treatment works;
(5) it is the national policy that areawide waste treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants in each State; and
(6) it is the national policy that a major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone, and the oceans.

PL 95-237: Endangered American Wilderness Act of 1978:

> Congress finds and declares that it is in the national interest that certain . . . endangered areas be promptly designated as wilderness within the National Wilderness Preservation System, in order to preserve such areas as an enduring resource of wilderness which shall be managed to promote and perpetuate the wilderness character of the land and its specific multiple values for watershed preservation, wildlife habitat protection, scenic and historic preservation, scientific research and educational use, primitive recreation, solitude, physical and mental challenge, and inspiration for the benefit of all of the American people of present and future generations.

PL 95-306: Renewable Resources Extension Act of 1978:

> Congress finds that:
> --the extension program of the Department of Agriculture and the extension activities of each State provide useful and productive educational programs for private forest and range landowners and processors and consumptive and nonconsumptive users of forest and rangeland renewable resources, and these educational programs complement research and assistance programs conducted by the Department of Agriculture;
> --to meet national goals, it is essential that all forest and rangeland renewable resources (hereinafter in this Act referred to as "renewable resources"), including fish and wildlife, forage, outdoor recreation opportunities, timber, and water, be fully considered in designating educational programs for landowners, processors and users;
> --more efficient utilization and marketing of renewable resources extend available supplies of such resources, provide products to consumers at prices less than they would otherwise be, and promote reasonable returns on the investments of landowners, processors, and users;
> --trees and forests in urban areas improve the esthetic quality, reduce noise, filter impurities from the air and add oxygen to it, save energy by moderating temperature extremes, control wind and water erosion, and provide habitat for wildlife; and
> --trees and shrubs used as shelterbelts protect farm lands from wind and water erosion, promote moisture accumulation in the soil, and provide habitat for wildlife.

PL 96-307: Forest and Rangeland Renewable Resources Research Act of 1978:

> Congress finds that scientific discoveries and technological advances must be made and applied to support the protection, management, and utilization of the Nation's renewable resources. It is the purpose of this Act to authorize the Secretary of Agriculture to implement a comprehensive program of forest and rangeland renewable resources research and dissemination of the findings of such research.

PL 95-467: Water Research and Development Act of 1978:

It is the purpose of this Act to assist the Nation and the States through water resources science and technology--

--to provide a supply of water sufficient in quantity and quality to meet the Nation's expanding needs for the production of food, materials, and energy;

--to preserve and enhance our water resources and the water-related environment;

--to promote conservation and efficient use of the Nation's water resources;

--to promote research and development, demonstration, and technology transfer dealing with both quality and quantity of water resources;

--to identify and find practical solutions to the Nation's water and water resources related problems;

--to promote the training of scientists, engineers, and other skilled personnel in the fields related to water resources;

--to foster and supplement present programs for the conduct of research, technology development and transfer, and innovative water resources management, conservation, and operating practices; . . .

--to better coordinate the Nation's water resources and development programs; and

--to enhance the capacity of the Federal water establishment, and of water interests nationwide for recommending to the President and the Congress changes in national water resources research and technology policy as appropriate.

PL 95-514: Public Rangelands Improvement Act of 1978:

The Congress finds and declares that--

--vast segments of the public rangelands are producing less than their potential for livestock, wildlife habitat, recreation, forage, and water and soil conservation benefits, and for that reason are in an unsatisfactory condition;

--such rangelands will remain in an unsatisfactory condition and some areas may decline further under present levels of, and funding for, management;

--unsatisfactory conditions on public rangelands present a high risk of soil loss, desertification, and a resultant underproductivity for large acreages of the public lands; contribute significantly to unacceptable levels of siltation and salinity in major western watersheds including the Colorado River; negatively impact the quality and availability of scarce western water supplies; threaten important and frequently critical fish and wildlife habitat; prevent expansion of the forage resource and resulting benefits to livestock and wildlife production; increase surface runoff and flood danger; reduce the value of such lands for recreational and esthetic purposes; and may ultimately lead to unpredictable and undesirable long-term local and regional climatic and economic changes;

--the above-mentioned conditions can be addressed and corrected by an intensive public rangelands maintenance, management, and improvement program involving significant increases in levels of rangeland management and improvement funding for multiple-use values;

> --to prevent economic disruption and harm to the western livestock industry, it is in the public interest to charge a fee for livestock grazing permits and leases on the public lands which is based on a formula reflecting annual changes in the costs of production;
>
> --the Act of December 15, 1971 /the Wild Free-Roaming Hoses and Burros Act of 1971/ (85 Stat. 649, 16 U.S.C. 1331 et seq.), continues to be successful in its goal of protecting wild free-roaming horses and burros from capture, branding, harrassment, and death, but that certain amendments are necessary thereto to avoid excessive costs in the administration of the Act, and to facilitate the humane adoption or disposal of excess wild free-roaming horses and burros which, because they exceed the carrying capacity of the range, pose a threat to their own habitat, fish, wildlife, recreation, water and soil conservation, domestic livestock grazing, and other rangeland values;
>
> The Congress therefore hereby establishes and reaffirms a national policy and commitment to:
> --inventory and identify current public rangelands conditions and trends as a part of the inventory process required by section 201(a) of the Federal Land Policy and Management Act of 1976; . . .

Executive Order 11644: Use of Off-Road Vehicles on the Public Lands (1972):

> It is the purpose of this order to establish policies and provide for procedures that will ensure that the use of off-road vehicles on public lands will be controlled and directed so as to protect the resources of those lands, to promote the safety of all users of those lands, and to minimize conflicts among the various uses of those lands.

--amended by Executive Order 11989 (1977).

## Appendix M: Monitoring Programs

The identification and measurement of desertification processes requires inventory and subsequent monitoring of the arid and semiarid lands of the Western United States aimed at describing the present condition of the resources of the area and the nature and pace of changes in the quality of the environment. Historical data are needed to compare with the present situation to detect change, and data from many different sources must be properly synthesized to accurately portray characteristics of the region.

A reliable and comprehensive monitoring system is needed to describe and quantify future trends in land conditions. This requires the coordinated application of advanced data collection, processing, and analytical techniques, as well as agreement on criteria and format to be used. Such information is essential to determine the extent of desertification and the nature and extent of possible remedial or mitigating actions.

### --Areas of Higher Risk

The processes contributing to desertification, or the impoverishment of arid and semiarid lands, occur in the zone of net water deficiency described in a Forest Service publication (Bailey, 1976) as the "Dry Domain," which covers most, though not all, of the 17 Western States. This discrete geographic area has been classified according to a broad synthesis of climate and dominant physical and biological characteristics. The Dry Domain can be further subdivided into a number of grassland and shrubland provinces according to a system which incorporates the potential natural vegetation regions of A. W. Kuchler (1966) and authoritative taxonomic systems such as Hammond's land surfaces and Köppen's climates.

Identification of natural regional boundaries assists the preparation of data bases for resource inventory. These boundaries define the area for purposes of retrieving information and establishing systems to collect and inventory data on identified targets so that changes and trends can be monitored.

### --Inventorying and Monitoring

Inventory and monitoring operations can be focused on specified indicators described in the ecoregions classification for arid and semiarid lands. Coordinated programs for managing problem areas can then be planned, based on consistent, measurable data covering the area of interest.

It is particularly important to distinguish between functions of inventorying and monitoring arid lands. An inventory is a description of basic characteristics of the lands in terms of geology, vegetation, soil, and water resources. The inventory presents a static picture of the basic resource situation. Monitoring, on the other hand, provides a means of assessing the dynamics of change in the land and its resources. Such monitoring allows one to determine the areas, the amount, and the rate of change. Monitoring of arid regions requires exchange of information between various disciplines, programs, and agencies. Monitoring is not an end in itself; rather, it provides a method for quality assurance and feedback into other aspects of desertification analysis. It provides the basis for the formulation of best practices for arid land management.

There is no distinct line between inventory and monitoring. In some instances inventory data will be utilized as the baseline from which the effects of an action are monitored, analyzed and fed back into the decisionmaking process. Conversely, monitoring data will be utilized to facilitate the development of inventories. Because these two types of data collection processes are interrelated--and in order to achieve effective and coordinated inventory and monitoring programs--all data collection efforts should adhere to the principles of quality assurance, data management, and information exchange discussed under monitoring principles.

Efficient monitoring calls for a mechanism that incorporates available data into data management and informational exchange systems. Such systems will provide for:

1. The efficient retrieval of information in a user-oriented format.
2. The exchange of information inside and outside the system.

Therefore, monitoring and inventory procedures should be designed to facilitate incorporation of data into a larger data base for land management.

When considering monitoring of the process of desertification, it is obvious that data collection and processing techniques will cross traditional discipline and jurisdictional boundaries. It will involve an interdisciplinary effort and will typically require cooperative arrangements between and among various Federal, State, and local offices to be accomplished in a systematic way.

A large number of agencies have responsibility to provide for the multiple-use management, protection, and development of the arid and semiarid lands of the Western United States. As a result of these responsibilities, these agencies are engaged in various forms of monitoring. These actions encompass resources above, on, and under the earth's surface, and they range in scope from local to national cooperative programs.

In summary, the definition of monitoring used by BLM is: "the systematic collection of data and analysis of changes or trends (short- and long-term) to determine (1) effects of an action on the environment, and (2) how an action complies with laws, regulations, policies, executive directives, and management decisions." By this interpretation the purpose of monitoring is to assist decisionmakers in determining the effects of an action, modifying or terminating an action, mitigating effects of an action, and/or reaching better decisions about similar actions in the future.

### --Monitoring Principles

Many land management programs develop and use data collection and monitoring systems designed to meet specific requirements and increasingly for broader regional objectives. While these requirements vary, principles of (1) quality assurance and (2) data management and information exchange need to be incorporated into monitoring efforts to provide reliable data and insure maximum value from often expensive monitoring programs.

Quality assurance is maintained through the use of standardized techniques, instrumentation, and methodology, with adequate auditing procedures throughout all stages of sampling, measurement, and recording in the field and laboratory.

Since reliability may vary, all data utilized in the environmental analysis and decisionmaking process should be accompanied by statistical estimates of reliability to ensure maximum value to other users. This applies to data and analytical information obtained from earlier environmental studies, inventories, and information stored in environmental data banks, in addition to data generated by ongoing monitoring programs.

How data will be collected, stored, and made available to all users depends upon storage and retrieval capabilities, whether the data will be stored and retrieved manually or by computer-augmented operations, and its availability in a format that is understandable and usable.

It is desirable to consider monitoring needs at the earliest possible stage in the analysis/decisionmaking process.

As has been stated, desertification is a complex and usually long-term process involving both natural and human elements, leading to loss of land productivity and human well-being. Desertification is a phenomenon deserving high-priority attention, insofar as its amelioration helps people. Three compelling needs for inventory and monitoring are:

#### (a) Monitoring for Scientific Understanding

The physical processes of ecosystem degradation--soil erosion and depletion, dune encroachment, waterlogging, and salinization--are well understood compared to other elements in the causal chain of desertification. The magnitude and rate of productivity loss from such physical processes are known only for a few scattered places and the relationship between productivity loss and human well-being is poorly understood. Development of a monitoring system must include research and experimentation to help provide the needed scientific understanding required to support a major effort.

#### (b) Monitoring for Awareness

Desertification is a subtle and slowly evolving process. People subjected to the effects of desertification may fail to perceive these effects as they adapt to the changing landscape or the occurrence may be obscured by short-term climatic fluctuations or "technological fixes." The willingness to take action to reverse or prevent desertification depends on such awareness at all levels of decisionmaking--local, national, and even global. A monitoring system should be educative and directly enhance awareness of the problem at all levels of its evolution.

(c) Monitoring for Action.

Preventing desertification in the drylands or reversing it wherever it has occurred may exceed the capacity of national resources and might be a misallocation of resources in the face of other compelling needs. It is necessary to have early warning for preventive action and assessment for selection for remedial action. Remedial actions are seldom dramatic and they require careful observation against baseline conditions to evaluate their progress or failure. A monitoring system should assist in selecting priority areas for action and effort, and to ensure that unanticipated impacts are detected early.

--Monitoring Requirements

Monitoring desertification is a long-term commitment that requires adequate institutional arrangement. Baed on the foregoing needs for monitoring--scientific understanding, problem awareness, and action selection--some requirements follow:

(a) The monitoring of physical processes needs to be linked to productivity loss. The inclusion of variables related to human activities and conditions, though difficult, is critical to the success of a monitoring system. Although climate fluctuations are not the primary determining factor in desertification, the pattern of weather and climate serves to dramatize as well as obscure desertification and, therefore, should be included in the monitoring system.

(b) The ultimate monitoring system must function on several levels: local, national, regional, and potentially global. Satellite technology provides a supplement to local and on-ground monitoring. Technical knowledge presently exists to arrest desertification, reclaim degraded areas, and increase levels of productivity. But this knowledge can only be effective when adapted to and used in the context of local management and ecological systems, and when it is periodically reassessed.

(c) A monitoring system should provide data appropriate to its end uses. These would include educational and demonstration functions as well as assistance in policy selection. A few simple, readily understood indicators are preferable to more complex measures. Involvement of the users in the monitoring process is mandatory.

--Levels of Monitoring

The emphasis in this section is centered on the data collection problem in the U. S. However, to function effectively, monitoring should proceed simultaneously at all levels: local and national at first, and regional and global ultimately. The system should provide:

a. effective collection of a limited number of critical data;

b. analysis, as appropriate, with special emphasis on the particularity of regional and national needs and additional emphasis on interrelationships between different indicators;

c. dissemination of analyses to decisionmakers and policy officials, especially at the national level but not to the exclusion of other levels;

d. interchange between and among the regional, national, and local membership in the monitoring network;

e. participation, insofar as possible, of farmers and ranchers whose economies may be improved by actions resulting from an effective monitoring system.

Resources are limited, as is the capability of individuals and institutions to absorb comprehensive data. Thus, one problem with existing monitoring systems has been an overaccumulation and underanalysis of data. This can also add needless expense. Moreover, implementation of elaborate systems sometimes removes control from the very people whom the system was intended to benefit. It thus seems advisable to agree upon the critical variables.

### --International Programs for Monitoring the Earth's Environment

The first recommendations for "national and regional action" contained in the International Plan of Action to Combat Desertification approved by governments at the 1977 United Nations Conference on Desertification held at Nairobi, Kena, favor assessment and evaluation of desertification using both existing data and new surveys, and monitoring of the dynamics of desertification as a continuing process to provide a feedback mechanism for national planning and action. Desertification should be measured:

(1) to indicate the relative seriousness of the situation;
(2) to standardize monitoring facilities and methods;
(3) to improve networks of climatological, meteorological and hydrological stations. Satellite imagery techniques should be employed where appropriate. National meteorological and hydrological services should provide ongoing assessments;
(4) to observe atmospheric processes; the state of vegetation and soil cover; dust transport; shifting of sand dunes; the distribution, migration, and abundance of wildlife; the condition of livestock; the phenology of crops; crop yields and changes in irrigated lands;
(5) to compile desertification maps and see that they are revised through periodic assessment using appropriate techniques which will be efficient and at acceptable costs.

The Nairobi Conference of 1977 approved two transnational projects which would establish desertification monitoring capabilities in South America and Southeast Asia. The design of these regional projects is continuing.

At the international level, the United Nations Environmental Program has convened several meetings on methodology for desertification assessment and mapping. The reports of meetings provide analysis of the state-of-the-art, some of the issues and problems yet to be addressed, and the character of future international work in this area.

A basic system for an adequate global and regional monitoring network is available within the U. N. EARTHWATCH structure. However, the existing system needs substantial improvement in the area of environmental assessment of phenomena and its relationship to human welfare needs. In addition, the EARTHWATCH system will benefit by establishment of regional and global assessment centers.

Despite an impressive array of collection activities and installations, important data gaps are reported to exist in charting the process of desertification. Decrease or increase of basic productivity of cultivated land frequently is only available through surrogate measures or estimates. Changes in productivity of rangeland are better documented but are difficult to chart from currently available data. Changes in albedo and dust storms are not recorded in any systematic way, and the relationship of albedo to productivity is not known for the West and Southwest of the United States. Thus, even with a substantial data base, the current system does not provide the information for a systematic documentation of the progress of desertification.

### --U. S. Programs for Assessing Environmental Data

A number of U. S. agencies and institutions have responsibility for monitoring and assessing environmental processes that are related to desertification.

U. S. Department of Agriculture

--Soil Conservation Service, especially activities in:

Land Inventory and Monitoring (LIM) Program
Soil Conservation Needs Inventory
Conservation Operations
Great Plains Conservation Program
Range Data Systems
Soil and Land Use Surveys

--National Forest Service

Department of the Interior

--Bureau of Land Management. Monitoring federal lands under its jurisdiction.

--Bureau of Indian Affairs. Managing rangeland on American Indian lands held in trust.

--Office of Surface Mining. Monitoring recovery from strip mining.

--Geological Survey. Work relating to land-use mapping, remote sensing imagery for monitoring, geophysical hazard forecasting, and monitoring availability and quality of existing water sources.

--Fish and Wildlife Service. Habitat survey.

Dept. of Commerce, National Oceanic and Atmospheric Administration

--Climatic Change Assessment. Related to the forthcoming Climate Diagnostic Center.

--National Weather Service. Both national and international coordination with World Weather Watch.

--National Environmental Satellite System (NESS). Continuinq worldwide monitoring of cloud cover, vertical temperature and humidity profiles, sea surface and land temperatures, and snow and ice cover.

NASA. Remote sensing research.

Army Corps of Engineers. Project-specific mapping.

Recent Statutory Authority: The USDA RCA 1980 draft Appraisal describes several inventory and monitoring activities on which data relating to condition of Western lands is based.

Beginning in 1929, Congress began funding inventory and monitoring activities through USDA in cooperation with other federal agencies, state and local governments and private sources. Activities included investigations on erosion control and national county Soil and Water Conservation Needs surveys.

More recently, Public Law 92-419 (August 30, 1972) authorized a land inventory and monitoring program. This program includes, but is not limited to, identifying prime agricultural producing areas and flood plains
use changes and trends. The law also directed the Secretary of Agriculture to issue a land inventory report on the nation's soil, water, and related resources every five years.

The Soil and Water Resources Conservation Act of 1977, Public Law 95-192 (November 18, 1977) authorized the Secretary of Agriculture to utilize SCS to conduct a continuing appraisal of the soil, water, and related resources of the nation. In addition, the Act requires SCS to develop a soil and water conservation program based on this appraisal. This program will direct future USDA conservation efforts and guide SCS activities that are part of those efforts. The purpose of the Act is to ensure that USDA programs for conserving our soil, water, and related resources are responsive to the long-term needs of the nation, which would include combatting desertification.

The Soil Conservation Service conducts periodic monitoring and assessment of rangelands, brush, and snow. Data show that range condition relates directly to erosion and water quality. Erosion is more likely to be excessive on rangeland in poorer condition. A 1977 special study by SCS states' range conservationists estimated the percentages of the Nation's nonfederal rangeland in excellent, good, fair, and poor condition. A similar range condition survey of State range conditions was performed in 1963.

SCS conducted national brush inventories in 1963 and 1973 (Bredemeir, 1973). The 1973 inventory showed 277 million acres of brush on nonfederal range, native pasture, pastureland, and some lands used for recreation.

SCS responsibility for snow survey activity is described as follows in USDA Administrative Regulations 1 AR 180:

> Responsibility for making and coordinating snow surveys in the western States and Alaska and preparing forecasts of seasonal water supplies in affected streams, for the purpose of relating available water supply to agricultural plans and operations.

State and Federal Data Coordination: A 1978 report by the Council of State Governments addressed the problem of coordinating data collection and use. Starting with the premise that information is the foundation on which sound decisions are made, the study found that a good deal of unneeded confusion results from failures in communication among data users and producers. Information necessary for land use management is frequently absent, sometimes improperly formatted or inconsistent. Also, it may be too expensive.

The two primary concerns of the report are (1) the improved coordination among agencies within each State collecting and using natural resource data, and (2) the improved responsiveness of Federal data producers to the needs of State users.

Four recommendations from the study were: (1) compile a single data directory listing all Federal data types and sources; (2) coordinate Federal interagency data to ensure compatible formats and reduce duplication; (3) monitor other federal agency requirements that stimulate State data use so producers might anticipate state needs; and (4) involve States more directly in the development and programming of Federal data collection activities.

Rangeland Assessment by BLM: The environmental analysis process has required BLM to describe objectively the condition of the public rangelands, the increasing public awareness, and the strengthening congressional support for better management practices. BLM now believes that better inventories of the basic resources of the public rangelands, including soils, vegetation, watershed conditions, wildlife habitat, etc., are still needed so that more effective land use plans can be developed.

The National High-Altitude Photographic (HAP) Data Base Program: In 1979 several government agencies agreed to a program for the acquisition of a nationwide aerial photography data base to serve their common needs. It is acquiring high-altitude photography of the conterminous U. S. Funding for this program is through interagency agreements. Agencies initially involved include the Departments of the Interior and Agriculture, NASA, EPA, and TVA. State agencies have been involved in the planning process. The photography is available for purchase and use by public and private interests through the Geological Survey.

The Domestic Information Display System (DIDS): A growing number of Federal agencies are cooperating to develop a computer system which could provide decisionmakers with almost instant access to statistics held by different government offices--and make interpreting them as easy as looking at maps. DIDS has undergone some changes but it has now been funded, and will soon be operational.

Monitoring Provisions of the Draft California Desert Plan: A practical test of inventorying the natural resource values of a region, and a good case study, is the situation which confronted BLM in preparing an Environmental Impact Statement for the California Desert. The final report which became available in January 1981 is a case study in how data are assembled to provide a current status.

Interagency Agreement Related to Classifications and Inventories of Natural Resources: This interagency agreement was signed in 1978 by the Bureau of Land Management (BLM), Fish and Wildlife Service (FWS), Forest Service (FS), Soil Conservation Service (SCS), and Geological Survey (GS) in response to several needs related to natural resource inventories including: exchange of inventory information among agencies in a consistent manner; and Federal and State coordination in data collection efforts, including where applicable the use of common multi-resource inventory and analysis procedures.

Congress has recognized that the collection and analysis of natural resource information must be coordinated. This need is reflected in legislation which focuses on assessment of the resource information

Principal objectives of the Agreement are to: (1) provide guidelines and assure administrative action to minimize duplication and overlapping efforts, and (2) to enhance and encourage coordination in overall data collection, data sharing, appraisal efficiency, program compatibility, while expediting technology transfer. In order to accomplish the objectives of the Agreement, an organized interagency operational structure was formed with assignments of personnel from each agency to various groups. This includes a Policy Group, Program Coordination Group, Research Support Group and Technical Work Groups. The five agencies, through the Policy Group, provide advice and consultation to the Director.

Early in the process of structuring activities to be accomplished in terms of this five-year agency effort, four major elements were identified: (1) classification, (2) data element dictionary, (3) inventory methods, and (4) information management.

(1) Classification: Sharing renewable resource information requires a common framework in which information about the land's characteristics can be organized. Ecologically-based classification systems for each of the four components which describe land in terms of soil, vegetation, water, and landform will provide the necessary hierarchical framework.

(2) Data Element Dictionary: After interagency classifications are available, common terminology must be used in this classification process, as well as in inventory methods and for information management.

(3) Inventory Methods: Common inventory techniques generating compatible data are the core of the Agreement and include what and how the commonly defined data elements will be generated.

(4) Information Management: This fourth element deals with how data are stored, tabulated, analyzed, and exchanged once collected.

The first progress report from the Policy Group in fall 1979 gave the following status of topics.

1. A "Proposed National Site Classification System for Renewable Resource Inventories and Assessments" has been endorsed by all five agency heads. The soils component is quite complete, but the vegetative component needs some modification and refinement. The aquatic and landform components must still be developed.

2. A general strategy for the development of common terminology for a data element dictionary has been approved. A comprehensive dictionary is installed on BLM's computer in Denver, Colorado, and elements which are of interest to at least two of the agencies are to be maintained in a special section as Five-Agency Data Elements.

3. Two major work areas identified in the inventory are to: (a) identify the major renewable resource inventories being conducted by each of the five agencies, and (b) identify specific areas for coordination among the five agencies. The inventory Technical Work Group is identifying inventories where coordination exists and where additional work is needed.

4. The last item addresses the development of standards and methods to facilitate data exchange (information management), which is divided into two parts: (a) Consider standards needed to exchange data--such as those necessary for digitizing mapped information or other data to be placed in a computer, and (b) study the different ways each agency handles and uses its data. The needs for information management standards are to be identified and standards completed by the end of FY 1980.

There are many stages in the work scheduled under the Agreement where a variety of individuals, groups, and organizations have an interest in the work being done. Other State and Federal organizations and interests will become involved as the need arises.

The Technology Working Group of the five agencies participating in this Agreement prepared a needed chart of monitoring responsibilities, both for point source and mapped areas, for the categories of soils, vegetation, water, and landform.

Potential of Remote Sensing: Remote Sensing is a tool to aid in gathering data about land conditions and can be applied with a minimum of ground verification.

Assessments of the potential effects of alternative land uses requires very large quantities of information on soils, vegetative cover, water, landform (topography), and climate and their relationship to each other. Both Federal and local management and planning decisions may require mapped as well as pinpointed information. The basic information required to satisfy national, State, or regional program planning, environmental impact statements, management plans, and day-to-day management operations, perhaps differing in resolution and format, places great demands on appropriate inventorying and monitoring activities. The integration, storage, processing, and management of all these kinds of data place demands on computer assistance. The collection of much of the needed data is increasingly performed by remote-sensing instruments situated on aircraft and spacecraft and thus able to obtain broad coverage with great rapidity.

The amount of information extracted from remotely-sensed data is dependent on the type of equipment used and the type of land to be sensed. The purpose and requirements of the data collection influence the cost and effectiveness of it, but a sensing system selected for parameters for arid lands could be initiated.

A particular advantage of remote sensing is its ability to cover remote areas or areas which do not justify the expense of ground surveys. Also, remote sensing represents a powerful analytical tool for eliminating the often high percentage of nonfragile and nonproductive areas of deserts that are of less concern, leading to the definition of the areas of critical concern that justify monitoring and documentation expense.

In 1978 a U.S. Department of Agriculture Remote Sensing User Requirements Task Force identified over 800 Forest Service natural resource information requirements which were compiled in a Data Users Requirements Task Force Catalog. Each requirement was addressed in terms of its current potential or its future potential for being classified, interpreted, or measured by remote sensing.

The review of the Remote Sensing User Requirements revealed that all these requirements can be divided into four major groups based upon application, as follows:

1. Classification and mapping applications. Units of land are classified by vegetative cover, nonvegetative cover, land use, land form, or disturbance.

2. Interpretive information for specific applications. Some examples might be the location of an unusual stress condition, potential landslide, geological hazards, and soil erosion.

3. Measurements of resource parameters. These measurements include linear distances, heights, numbers, area and other expressions of the size, quantity or quality of basic resources.

4. Observation and counts of occurrences. This category is defined as the determination of the presence or absence of an item such as erosion.

With remote sensing tools, especially Landsat, a resource integration and monitoring program is feasible. Existing and new data related to geology, topography, soils, vegetation, present land use, and climate can be taken and placed in a uniform scale and known degree of accuracy to provide reliable base maps for easy reference and use.

Qualitative or quantitative data can be acquired for periodic surveillance concerning important desertification phenomena such as soil moisture, shifting and migrating sand dunes, changing vegetation patterns, degrees of salinity and alkalinity in cultivated areas whether periodic or permanent changes, and other phenomena. Repetitive data can be obtained rather quickly and cheaply from Landsat satellites with good resolution sufficient for broad reconnaissance purposes. The temperature-measuring capability of Landsat-3 and of the NOAA satellite (although at less resolution than Landsat) can be of great value in monitoring soil moisture. A study of desertification should be conducted initially on a reconnaissance level.

## Appendix N: Research Needs

Many of the topics in the disciplinary and interdisciplinary research related to desertification described in this Appendix have been investigated or are part of ongoing research. Some are not. It is important to point out here that the relationship among the reserves that constitute the resource base are given increasing attention by the scientific community and the research needs on the subject have lately been better identified. As an example, on February 1981, in Madison, Wisconsin, a group of scientists and leaders met to discuss the soil and water resources research priorities of the Nation. During this meeting six research areas were selected as the most important:

- sustaining soil productivity;
- developing conservation technology;
- managing water in stressed environments;
- protecting water quality;
- improving and implementing conservation policy;
- assessing soil and water resources.

In each case the dependence of the quality and quantity of the whole resource base on each of the components was stressed, together with the need for consistent and accurate assessment through adequate data collection and analysis (Larson et al., 1981). What follows shows the direction of, and the focussing on, new and better knowledge needed to prevent, remedy and arrest desertification.

### 1. Climate

#### a. Climate and Weather Variability Prediction

Latitudinal and longitudinal shifts in the air flow patterns of the Southwest can have profound effects on the climate. Such shifts are evidenced by drought when, for example, winter storms are diverted northward for extended periods of time. Although these synoptic patterns have been observed for many years, their mechanisms are not well understood. Research is needed in the following areas:

- Integration of atmospheric experiments to include the heating function, microscale, mesoscale processes, and the effect on and of vegetation;

- Determination of the "resiliency" or ability of water resources systems to cope with adverse climatic conditions. For example, interactive research is needed among climatologists, plant biologists, and crop specialists for the establishment of production functions of plants as well as for estimating possible large-scale consequences of droughts and desertification;

- Research on deterministic physics-based climatologic modeling, and on climatic change. Such research may eventually lead to reliable climatic forecasts;

- Research should continue in an effort to gain basic understanding of man's potential impact on climate (e.g., the long-term effects of increased amounts of carbon dioxide in the atmosphere); and

- The climatic trends and variations in arid and semiarid lands (ASAL), taking into account the micro-, meso-, and macro-scale processes, using tree-ring analysis, for example;

The following questions need to be answered. Are there desertification trends? Complexities arise when one attempts to assess the trend, i.e., are the Southwestern deserts growing or becoming smaller? A review of Southwestern history indicates that vegetation was more abundant 100 years ago than today. Reduction of vegetation should change the albedo of the area and, subsequently, the climate, but has this occurred? If so, is the trend continuing?

The air quality in the large urbanized portions of the Southwest has markedly deteriorated in the past 50 years. The rapid increase in population and industrialization in these areas has produced this problem. The influence of air quality on the climate could range from trivial to significant and could be manifested, for example, in changes in precipitation (positive or negative) due to the effects of air pollutants on weather systems, and changes in the radiation balance which could also affect precipitation and temperature.

Other important topics are the influences of dust storms on climate. Examples of questions to be addressed are: What are the trajectories and extent of dust storms? What are the main anthropogenic factors causing them? What is the effect of suspended dust on precipitation?

For planning purposes, knowledge of the probability of extreme weather events (floods, droughts) is also required. In some cases where data are limited, simulation techniques for generating synthetic time series are invaluable. With the inclusion of the response functions and the economic factors, the simulated time series can be evaluated in a decisionmaking framework.

### b. Drought

The occurrence of severe droughts in the past has in effect spurred changes or adaptations in agriculture, and has promoted conscious efforts to raise the level of drought adjustment so that the next drought would have a lesser impact. At each of three major drought occurrences--the 1930's Dust Bowl, the 1950's and 1970's droughts--there was a flurry of activity and concern. Each brought a new or additional emphasis in adjustments. Each generated new research directions.

Some of the scientific and technological tools that will aid in drought mitigation strategies include:

- Improved weather and climate prediction on the time-scale of months and seasons;
- Improved assessments of land and crop conditions to provide early warming of drought incidence, and surveillance of drought severity;
- Integrative models of the interactions between soil, crop, weather, water supply, economics and other variables so that the potential impacts of drought (and other climatic stresses) may be used as a planning aid; and
- Scenarios of future droughts considering timing, duration, severity and extent of drought as a further guide in the design of research and management programs.

Some recommended research topics on agricultural droughts needing more support concern irrigation and water supply conservation:

- Better methods of estimating future water demands;
- Increased effectiveness and reduced cost of retardation of evaporation by such techniques as monomolecular films;
- Various alternatives, and the full environmental effects, of reducing transpiration losses from phreatophytes by chemical control;
- Crop-yield water requirement relationships;
- Development or strengthening of more efficient water application systems;
- Additional research on managerial models of water use; and
- Development of alternative models of water supply management to overcome deficiencies.

The recommended research topics that follow convey a broad perspective which could lead to flexible modes of adjustment to urban and industrial drought problems. Much of the research for agricultural droughts is of direct benefit for urban droughts also, particularly water supply protection, weather modification, land use regulation, and prediction and forecast research. Some research activities specific to urban droughts are:

- Improved desalination and water reuse technology;
- Improving conventional water supply systems;
- Altering water demand; and
- Social problems of water reuse.

### c. Acid Deposition

This could be a special stress on the arid ecosystems, one which is increasing in importance, and should be considered. Acid deposition, in any of its many compositions or forms, causes deterioration of vegetative cover, and in this fashion may initiate and/or contribute to desertification.

Acid deposition includes pollutants, both soluble and insoluble, deposited from the atmosphere. This term has been used because the most obvious deleterious effects have been attributed to the $H^+$ ion in precipitation. Other effects, at least as serious, may be due to mercury, cadmium, fluoride, lead and various organics.

Increased acidity in rain has been observed in localized areas in the Midwest and along the West Coast, and the potential exists for acids and other pollutants in Colorado, Wyoming, and other nearby States from full development of fossil fuels.

Extensive regions of the Western States are both sources and receivers of acid deposition impacts, and on these lands timber and forage production and other resources may be sensitive targets of atmospheric deposition. In addition, the long-range transport of acid rain constituents from sources in arid and semiarid regions may have adverse impacts several hundred miles downwind from the source in more humid environments.

Some of the research needs in this area are:

- Identification and measurement of the anthropogenic and natural sources of emissions causing acid deposition in the Western States;
- Physical and chemical properties of atmospheric transport in dry lands;
- Processes and composition of wet and dry deposition;
- Effects of acid deposition on the organic, inorganic, and nutrient components of soil in arid/semiarid biomes; and
- Biologic effects on vegetation: crops, forests, rangeland, bacteria, fungi; and on animals: wildlife, domestic animals, and humans.

## 2. Soil

### a. Soil Salinization

Soil salinity is a localized problem, very serious in some instances. Although considerable work has been done on soil salinity, and the technology is generally well understood, more research is needed in selected areas. Some of the areas of interest are:

- Effect on animal and plant nutrition of soil-plant systems with high amounts of calcium and silica;
- Proper management of both cultivated lands and wildland watersheds;
- Gradual salinization of soils, disposal of salts, and soil rehabilitation;
- Efficient and economic irrigation management strategies to reduce the detrimental effect of saline irrigation return flow from agricultural lands;
- Effects of soil salinity on microbial mediated nutrient transformations such as nitrogen and sulfur cycling;
- Effects and methods to mitigate salinization of water supplies from retorted oil shale and from coal mine spoils; and
- Long-term effects of abandonment of lands due to salinization.

### b. Reduction of Erosion

Research in soil erosion should be tied directly with the soil potential concept of land use planning, including climatic conditions. The soil potential rating (McCormack, 1974) is the ability of a soil, aided by modern technology, to produce or support a given structure or activity.

More information is needed for erosion control on:

- Land surface condition;
- Wind barrier vegetation;
- Chemical soil surface stabilization; and
- The mechanism by which soil particles move out of the normal soil structure into rills and then into gullies.

### c. Land Reclamation and Soil Loss Equation

In reclaiming and rehabilitating land in arid/semiarid regions, some specific problems are present that could lead to desertification. Some of the factors of concern are:

- Soil water (drainage) - water movement through and over the soil including infiltration, permeability, water-holding capacity and their relation to storm drainage, plant growth and sewage disposal;

- Soil slope - measured by degree of slope and shape;

- Soil erosion - the present condition during overland flow and susceptibility to future erosion;

- Soil depth - depth to bedrock and other material difficult to excavate;

o Soil stability - engineering properties that determine suitability for subgrades, sanitary landfills, etc. Shrink-swell characteristics and presumptive bearing values which affect foundations are also included;

o Soil wetness - usually expressed as depth to water table, stream overflow and collection of surface runoff; and

o Soil permeability - capacity for movement of water through the soil.

o Soil water quality - generally not given enough attention, even though adverse quality parameters (e.g., salinity) are included in the final assessment of land use.

o Methods of integrating regional factors such as climate, atmospheric diffusion in complex terrain, or atmospheric temperature gradients, all of which impact on the ultimate development of a region, with other lands characteristics, should be developed.

Refinement of the soil potential concept in land-use planning to include climatic considerations with reference to semiarid mountain terrain is also recommended. This rating in general integrates the yield or performance level and the difficulty of applying treatments to overcome or minimize the effect of soil limitations.

At present no standard methods exist for measuring soil loss from arid and semiarid lands, and in its present form the Universal Soil Loss Equation (USLE) is not usable for western rangelands (Herbel, 1980). Improvement of the USLE would require research on the rainfall factor (R), the slope-length factor (SL) and the erosion factor (K).

The mesoclimate and soil factors should be studied jointly in terms of soil erosion and stream sedimentation, which is a major water pollutant. Research sites should include wildland watersheds, lands after timber cutting, oil shale spoils, and strip mine overburden. Another topic of interest is the reclamation of disturbed land, returning it to its natural condition or another preselected one.

Paleoclimatic history of the high plains needs investigation to determine whether existing deteriorated soils can be restored under today's climatic conditions (Curry, 1980) and at what rate the soil actually forms.

## 3. Water

The allocation of a scarce resource, water, and the effects of this allocation, are viewed by scientists as central to practically all the issues generated by competing demands and demographic changes in the dry areas that may lead to desertification. Increased understanding of nature's hydrologic systems is necessary for successful resolution and avoidance of this and related problems.

Major emphasis of research in water resources management has been directed toward methods for increasing water supply, such as desalinization and weather modification. Emphasis should be shifted more toward the conservation and protection of water resources, specially in water-short areas.

Some general research concerns are to:

- Develop methods to increase irrigation efficiency;
- Conduct studies on hydraulic properties of aquifers - natural recharge - infiltration - contamination problems;
- Develop hydrological simulation models capable of integrating surface and ground water quantity and quality characteristics;
- Conduct studies on augmentation of water supplies through water reuse, salvage of diffuse and emphemeral desert basin runoffs, water importation--problems and impacts;
- Develop methods for calculating minimal water/energy budgets for agriculture and other land uses that permit optimal use of resource base and avoid the hazard of desertification;
- Conduct long-term studies to determine the impact of lesser quantities of water on the soil and the timing of water for each plant species. species;
- Develop methods to control and utilize tailwater more effectively; and
- Evaluate water yield increases from vegetation manipulation.

### a. Groundwater

Severe quantity and quality problems are facing groundwater systems throughout the country as groundwater resources are mined, contaminated, and wells are closed or depleted. It is noteworthy that groundwater is a major source of water supply in the Western and Great Plains States. There is inadequate technical and related data about groundwater resources--information needed to make sound decisions about regulations and management--to fully understand the physical and chemical processes involved in the changes occurring within the aquifer.

Studies are needed on water mining; artificial recharge programs; well and playa lake management and modification; assessment of diverse irrigation and cultural practices; potential for pesticide and fertilizer contamination of aquifers; natural and induced recovery of a contaminated aquifer; waterlogging of soils and its effect on salinization of ground water; impact on aquifers of underground storage of liquid wastes and excess surface runoff; recharge of treated municipal wastes into shallow and deep aquifers, and pressure buildup consequences.

Other areas needing research are: groundwater conservation and reuse practices, their social and economic effects; demand control methods for diverse uses; management alternatives assuming groundwater as a non-renewable resource: and equity in multiple use of scarce groundwater and total water resources.

The augmentation of ground water supplies through salvage of diffuse and ephemeral desert basin runoff should be explored. The use of other artificial means to minimize diffuse system losses, maximize use of aquifer storage capacity, and extend the developable ground water supply should also be investigated.

### b. Water Conservation, Supply, and Demand

The discussion in this section includes water quantity and quality considerations.

It has been suggested that negative incentives constitute the greatest deterrent to effective water conservation. These negative incentives are, for the most part, legal or institutional. Research is needed to determine the extent to which these negative incentives are valid, and to suggest mitigating alternatives. Presently, the only method used to regulate the amount of groundwater pumped on the Texas High Plains, for example, is well spacing. Legal and institutional research can provide alternatives which may better suit the interests of High Plains residents. For example, subsidization practices should be examined.

Some research topics are:

- Case studies of demand management by pricing, metering, education, regulation, etc.;
- The new phenomenon of limiting growth (urban or agricultural) according to the criterion of water availability;
- The way in which various states look at evaluating demand within existing laws;
- Variability of water availability, and the likelihood of immediate institutional response to changes; and
- Case studies of the recent drought in the American Southwest in terms of what worked and what did not.

### c. Water Reuse

Water reuse can be an effective method for meeting some of the increased demand on limited fresh water supplies. While technological advancements necessary to reuse water effectively have been made in recent years, deficiencies still exist. Most technological innovations have been concerned with the reuse of wastewaters for industrial purposes, with little regard to agricultural reuse. Agricultural reuse systems should be a topic of intensified research and investigation. Economic analyses should be undertaken to determine potential savings through reuse in terms of short- and long-range benefits, as well as savings in treatment costs and benefits from nutrients contained in wastewater.

Probably the greatest deterrent to water reuse that exists today is the question of risk associated with health effects. In addition, because of quality deterioration, water cannot be reused indefinitely in a closed cycle. Methods to treat or dispose of water no longer reusable must be found which are environmentally sound and economically feasible. For agricultural reuse it is important to know the effect that certain contaminants, especially organic chemicals, will have on certain crop productivity and soil quality. The fate of potentially harmful organic chemicals needs to be documented.

## 4. Flora and Fauna

### a. Stressed Ecosystems Studies

Desertification, drought, flash floods, and dust storms are some of the stresses on arid/semiarid areas. Not much is known about the biota responses to stresses, nor the rate of recovery from a single event and/or combination of events. The effect of extreme climatic conditions on microbial-mediated nutrient transformations in arid/semiarid lands should be researched, e.g., the effect of direct solar exposure, reaching temperatures of 180°F, the mitigating influence of shade from vegetation, the availability of moisture, etc., all having a direct effect upon microbial propagation. Also, an increased effort must be made to define the basic functional responses of crops, plants, and animals to weather and climate so we can improve our present systems of crop, range, and livestock management. It is also important to better understand the impacts of diverse land uses, e.g., dry farming, grazing, mining, urbanization, etc., on the arid/semiarid biomes, and why and how desertification may result from these impacts. The use of control ecosystems (national parks, biosphere reserves) to distinguish between natural and induced changes in biotic systems can be extremely useful as well in following increasing and decreasing trends in their quality.

New methods to control noxious plants, and the assessment of their impact on the surrounding systems should be given stronger support.

### b. Salt-Resistant, Drought-Resistant Plants

There is a need for rethinking and reevaluating the traditional approach to salinity, which has been devoted almost exclusively to environmental manipulation. Most needed are the addition and vigorous application of new, biological, and specifically genetic dimension to research and development dealing with salinity. Some of the topics for research in this area are:

- Methods for increasing the existing germplasm collections through the addition of salt-tolerant species and varieties;

- A judicious choice of promising species which (a) are of actual or potential importance as sources of food, fodder, fiber, medicinal or industrial materials, or biomass for energy, and (b) have an evidenced genetic potential for salt tolerance; and
- Basic research into the mechanisms of salt tolerance and sensitivity.

Efforts should be made to develop plant-growth stimulation models with a data base sufficient to lead into recommendations for optimal water use under a variety of conditions: e.g., unlimited water availability, limited water at various growth stages, limited water application rates, and drought conditions. The models could be used to determine:

- Physiology of plants and crops native and/or adaptable to arid and semiarid lands (using high salinity and natural water for irrigation and various irrigation methods);
- Market values of arid and semiarid crops and development of appropriate technologies to make production of such plants economically attractive;
- Land classification schemes to define compatible land-plant-animal-climate systems;
- Ecological sensitivity of dry lands to temporary and persistent weather changes;
- Climatic and hydrological effects of agricultural land use (with emphasis on the effect of introducing native and non-native species to arid and semiarid lands);
- Drought tolerance and protoplasmic qualities in mesophytic higher plants;
- The mechanism by which some plants survive very high temperatures leading to collection and breeding of heat-tolerant varieties of valuable plants; and
- Improved methods of reforestation and rehabilitation of semiarid lands.

### c. Wildlife and Grazers

When desertification occurs, animals are affected as well as vegetation. Some areas of faunal research may include:

- Transplant and propagation of endangered species;
- The extinction process of endangered species through time and the induced extinction due to desertification;

- Development of economical inventory techniques for rangelands;
- Development of improved classification schemes for rangelands;
- Species of grazers that could survive in distressed ecosystems;
- Grazing tolerance of distressed ecosystems;
- Game ranching alternatives to domestic livestock;
- Assessing the introduction of exotic species in stressed ecosystems;
- Impact on domestic and wild animals of the dewatering of streams.
- Vegetation management to minimize herbivory.
- Integration of knowledge of grasshoppers and locusts and their effect on desertification.

## 5. Population Dynamics: Growth Patterns

Native populations of the U.S. drylands seem to have evolved social systems incorporating methods of resource use that maintained them in dynamic equilibrium with arid environments. With the European colonization of the New World and with the conquest of the West, new modes of coping with a hostile environment were applied. The United States has evolved highly integrated economies and transportation networks, and dry area populations have become somewhat less vulnerable to the effects of desertification and drought. In such moderate- or low-risk situations, the climate and relative uncrowdedness of arid lands have encouraged movements into the Sunbelt. A net migration from the Frostbelt is taking place that is taxing, in some instances heavily, the resource base of certain portions of the Western States. Also, the population and economic shifts from farm to urban-related activities and the changes in land uses have resulted in strong environmental changes, such as the local abandonment of field systems, including terracing, small, ephemeral stream dams, and primitive irrigation networks that, in some cases, can be a factor in desertification (Kates et al., 1976). While excessive population growth increases demands on the resource and may lead to its impairment, some population is needed to maintain the labor-intensive long-term productivity and to transmit knowledge of the evolved adaptive technology to other generations.

While the American Southwest appears to represent a successful example of maintaining large populations in arid zones without resource impairment, some symptoms of declining productivity may suggest that the area may instead have achieved a tenuous, short-term environmental equilibrium. Should the Western resources development go to higher levels of agricultural and energy production, and or urbanization, this equilibrium may be disturbed. In relation to this possibility some of the topics that need study, or continued support, are:

- The traditional methods of coping with the inherent variability of arid lands, including strategies for dealing with risk. Findings should enable better prediction of the consequences of altering or eliminating these procedures;

- The assessment of how people living in drylands evaluate the potential return on and vulnerability of their investments, as well as how they perceive their options. The question of what motivates successful local participation in development and anti-desertification efforts should also be addressed;

- The dependence, if any, of the social systems on institutional supports such as federal subsidies;

- The effect on the social systems of increasing urbanization;

- The economic and environmental costs of, and impacts on, the arid regions for securing water, energy, and raw materials for growing urban centers. Example: water resources for the city of Tucson come at the price of retiring farms around the city.

## 6. Socio-Behavioral Factors

Research related to social-behavioral aspects should include, but not be limited to:

- Investigating incentives which create self-regulation, rather than government regulation, of water and other resources for more efficient use;

- Analyzing individual and group perception of arid/semiarid lands resource problems, and the relation of these perceptions to the manner in which conservation and management programs are being conducted;

- Assessment of the extent to which public participation can/should be incorporated into resource allocation decisions;

- Assessment of the nature and content of social and political conflicts between urban and rural interests in arid areas;

- Investigation of the social consequences of changes due to desertification, in dominant economic activities in arid regions, e.g., from mining and agriculture to manufacturing and tourism;

- Analysis of the impact of localism and regionalism in policy issues debates, i.e., "Sunbelt" vs. "Frostbelt," energy-producing states vs. energy-consuming ones, etc.;

- Assessment of the extent to which cultural background and values contribute to desertification of arid lands;

- Assessment of social effects of large-scale vs. small-scale technological responses to aridity and desertification;

- Investigations of methods to effect short- and long-term changes in attitudes and values relevant to drought, aridity, and desertification;

- Examination of the impacts of special growth patterns on the development of arid and semiarid resources, i.e., retired persons, fixed income groups, transients, etc.; and

- The "boom-town" phenomena, or the development associated with energy and mineral extraction/production, and large civil and defense works.

## 7. Economics

Increased recognition is given to the need for making the best long-range use of natural resources - an approach that often conflicts with the conventional economics of each individual or entity for maximizing returns. In the case of drylands, the recognition of the limitations of the system and the hazard of desertification fosters the interest in conserving, sustaining, and enhancing the quality of the renewable resource base land. It is also recognized that these resources must be protected from irreversible damage. Another concern related to maximizing the life-cycle value, rather than the short-term value, of nonrenewable resources, is groundwater without natural recharge.

One approach to research of economic dynamics problems may be subdivided according to whether (a) they are resources of the arid region itself; or (b) are obtained by exchanges of resources or services with other regions. Solutions may be sought, then, within the region, from those whose solutions must necessarily involve interactions with other regions.

Current thinking is toward the explicit recognition that traditional economics emphasizes short-range dollar values, which results in treating the returns of extracted resources as current income rather than as withdrawal of capital. A newer approach is directed toward a broader framework of valuation where prices of extracted nonrenewable resources are predicted based on the cost of replacing them with renewable resources.

Economic studies on dispersed vs. concentrated uses are needed. One example is provided by the values assigned to water according to use. While typical cost of water used for irrigated agriculture may vary from $5 per acre-foot to $50 per acre-foot, water used for domestic purposes costs approximately $120 per acre-foot; water used for secondary oil recovery purposes is rated at a value of approximately $600 per acre-foot. Therefore, if economic forces alone were to determine where adjustments in water consumption were to be made, agriculture and its supporting industries would bear most of the burden. Studies to estimate the impact that response to such water values would have on agriculture in arid and semiarid lands, and to investigate means of mitigating adverse impacts that would certainly accompany any shifts from agriculture are needed. Similar studies on other resources affected by desertification and their shifting values are needed as well.

Energy costs, rather than declining water supplies, may markedly reduce irrigation in the West. For this reason, it is urgent to conduct studies aimed at solving the problems presented by the increasing cost of energy, and inefficiency of some irrigation systems. Research is also needed to evaluate alternative energy sources for powering irrigation wells. Such alternative energy sources will include solar, wind, and biomass, all of which are frequently associated with arid and semiarid lands.

As has been stated, the present average cost of water for irrigation varies from $5 per acre-foot to $50 per acre-foot, whereas it has been reported that the energy sector is willing to pay a much more substantial price. The price differential is likely to cause a major shift of irrigation water to energy-related activities. The corresponding socioeconomic impacts of this trend and the associated local and regional economic tradeoffs should be studied.

Other topics to be studied include:

- The implications of developing and exporting resources of arid lands for utilization outside arid regions that would not contemplate rehabilitation of impacted areas;
- The costs and benefits of applying national environmental standards to arid lands;
- The development of methods to better quantify and analyze the losses due to desertification; and
- The development of methods to measure the benefits accrued from preventing and arresting desertification.

## 8. Policy Decisionmaking

The central theme of policy analysis is the investigation of governmental decisionmaking. As such, it seeks to identify the process by which public issues are recognized and the ways in which solutions are both devised and implemented. Decision analysis can be concerned with evaluation of implementation and the feedback of such evaluation into the decisionmaking continuum. Although it is a generalized approach, policy analysis is usually conducted in a limited area of interrelated problems and solutions, i.e., natural resource/environmental policy, forest policy, etc.

Research related to policy decisionmaking aspects concerning the desertification problem should include, but not be limited to:

- Investigating the advantages and disadvantages and, if possible, the political feasibility of discouraging population migration to arid and semiarid regions, that is, curbing the long-term trend of population movement from the "Frostbelt" to the "Sunbelt;"

- Developing more acute methods to identify, measure, quantify, and evaluate all commensurable and noncommensurable benefits and costs, including risk, in a multiobjective framework; and

- Assessing the effects of, and possible changes in, national environmental policies in arid and semiarid regions against a framework of environmental protection and arid economy maintenance, and projected energy development.

Improved techniques for quantifying and evaluating non-economic costs and benefits will allow local, State, and Federal governmental agencies and individuals to make more rational decisions in developing and allocating resources so as to prevent deterioration. Furthermore, an overall systems approach to the resource base management problems, with a thorough consideration of economic, environmental, quality, esthetic, quality of life, social well-being, and legal viewpoints will allow an informed public to better identify and select both optimal alternatives and consequences.

The following list of research topics associating institutional and legal aspects with decisionmaking typifies the need for and significance of research on these aspects:

- Involve decisionmakers in research on policy decisionmaking. Mechanisms should be developed for presenting and packaging the various research results on policy decisionmaking aspects in a form usable and understandable by decisionmakers.

- Explore decisionmaking techniques for displaying, identifying, measuring, evaluating, and integrating socio-environmental (non-market) values and the economic objectives on an equal basis;

- Examine the distributional effects of certain policies related to soil and water conservation;

- Launch investigations that include the nontraditional scenario game-playing, such as:

  - regulating irrigated agriculture;
  - assessing the effects of enforcing a 160-acre limitation on irrigated acreage for Federal reclamation projects;
  - limiting or stopping agricultural subsidies;
  - determining social resiliency and/or irreversibility of actions.

- Identify and evaluate types of Federal and State policies which have been modified in response to arid conditions (e.g., the Homestead Act was modified in its application to the West by the Desert Land Act);

- Identify governmental policies unique to drylands and evaluate their applicability for humid regions which have, or may have, problems of scarcity. There is already a tendency for Western water law concepts to move east;

- Assess the extent to which there is a need for, and existence of, an arid region urbanization policy;

- Examine the legal and political implications of a large-scale weather modification policy;

- Identify land types and land use patterns in arid and semiarid regions in order to establish the parameters for alternative land-use policies in the desertification-prone areas;

- Assess groundwater policies, the extent of depletion, and its impact on the quality of drylands;

- Assess the political, legal, and technological feasibility of water reuse policies; and

- Assess the efficiency of drought insurance as an alternative to investing in drought-proofing facilities (such as reservoirs).

## 9. Institutional and Legal Factors

Research on institutional topics attempts to identify the formal and informal structures and processes of government and society which have either a legal or common usage base, and are generally accepted by society as authoritative. Part of the identification process involves defining the role performed by institutions in the overall governmental process.

In the special case of research on legal and institutional arrangements in arid and semiarid locales, efforts should aim at, but not be limited to, investigating the organizations that would permit or that could strain or restrict efficient resources use. For example, work needs to be done on how we go about effecting changes in water use in arid areas, where necessary, while protecting individual equity, the economy, and preferred modes of life with respect to energy, agriculture, municipal and industrial development. There is also a need for a better understanding of arid lands institutions concerned with reducing risk (e.g., cooperatives, credit extensions, storage facilities), allocating scarce resources (e.g., water rights and systems of land tenure), and curtailing production in bad years (e.g., soil banks and price support systems). The mission of such institutions is to minimize the probability of resource degradation and consequent economic and social dislocation.

Criteria for evaluating the effectiveness of these institutions should include a measure of the flexibility of their responses to the special nature of arid environments; their contribution to the preservation of ecosystem functions should also be assessed.

One example of potential benefits from such research is on the determination of the institutional arrangements that would allow orderly transfers of water during emergencies to mitigate the effects of droughts and/or desertification, since technically such transfers are already possible. As it is, very limited planning exists to deal with these contingencies. Improved techniques for evaluating non-economic costs and benefits will allow governmental agencies and individuals to make sound decisions in developing and allocating resources when the quality of the land is at stake.

The following list of research topics associated with institutional and legal aspects could be applied for the prevention and arrest of desertification:

- Documentation of institutional constraints and relative advantages: Are there inhibitions for choosing the most effective institutional arrangement? What is the functional relationship among local, State and regional entities? From a national, regional, or State perspective, what are the relative advantages of policy uniformity vs. diversity?

- Examining the transferability of water rights, particularly their effect on implementation of water conservation practices and policies, changes in water use and location of use, reuse and interstate/international issues: The means or method to effect water rights transfers should be included;

- Building the unit return (product, services) per unit input of water into the allocation equation approach, e.g., mining and agriculture vs. manufacturing and tourism. Consideration should be given to the decline in productivity of lands from which water is collected;

- Comparative and evaluative research of planning at the local, State, regional and national levels with the private sector to generate an appraisal of the government/private "mix," influence and effectiveness: What have been the consequences where land use planning has been carried out?

- Assurance of alternative means for local institutions to take into account in their decisions extra-local resources and conditions. Examples:

  (i) There is a well-established legal doctrine that local (land) planning authorities must take into account extra-territorial consequences of their decisions. What would be the consequences of applying this doctrine to the institutions that control other resources in arid regions - stream flow, weather modification, groundwater?

(ii) Veto authority in the hands of higher government institutions, e.g., national or State agencies having authority to veto decisions of State or local institutions, respectively

(iii) Evaluate the effectiveness of grants-in-aid.

- Analysis of institutional arrangements for regulating, funding, and protecting areas losing water in interbasin transfers. Such institutional arrangements in the United States have potential transferability to other arid areas in the world;
- Institutional arrangements for maintaining instream flows in areas of water scarcity;
- Investigation and identification of Indian water and other resources rights and assessment of institutional ways for protecting both Indians and other users;
- Inquiry into the institutional arrangements for implementing Indian tribal control within the framework of existing agencies in matters of environment and energy;
- Cross-national and interstate study of institutional approaches to water scarcity and its effect on land conditions;
- Assessment of the extent to which state power in land and water regulation is inhibited by the major federal presence in arid lands;
- Appraisal of institutional methods for effective coordination between resource planning and land use planning, in the context of arid conditions and in contrast to humid conditions;
- Review of institutional methods for effective coordination among national, state, and local resource management agencies;
- Identification of institutional barriers to land treatment methods for water quality control in arid areas;
- Assessment of existing and alternative interstate compacts and regional organizations to resolve domestic and international problems;
- Evaluation of institutional arrangements for resources conservation on both a short- and a long-term basis;
- Research of institutional methods of minimizing damage from flash floods;
- Analysis of the effectiveness of present institutional arrangements for protecting long-term public interests in arid areas, rather than protecting short-term private interests; and

- Assessment of the most effective scope of resource management institutions (local, State, and national) in dealing with problems in arid areas.

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